THE PHILIPPINE
JOURNAL OF SCIENCE

ALVIN J. COX, M. A., PH. D.
GENERAL EDITOR

SECTION A
CHEMICAL AND GEOLOGICAL SCIENCES AND THE INDUSTRIES

VOLUME X
1915

WITH 30 PLATES AND 40 TEXT FIGURES

MANILA
BUREAU OF PRINTING
1915

CONTENTS

No. 5, September, 1915

No. 6, November, 1915

THE PHILIPPINE
JOURNAL OF SCIENCE
A. CHEMICAL AND GEOLOGICAL SCIENCES
AND THE INDUSTRIES

VOL. X JANUARY, 1915 No. 1

PAPAIN: ITS COMMERCIAL PREPARATION AND DIGESTIVE PROPERTIES

By DAVID S. PRATT
(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

TWO PLATES AND 4 TEXT FIGURES

Papain is the name usually given to the proteolytic enzyme elaborated by *Carica papaya* L. and secreted in the milky latex that forms a prominent characteristic of the plant. The papaya tree is normally an erect plant, from about 5 to 10 meters in height at maturity, seldom branched, with a soft trunk and a crown of large palmately lobed leaves. The plentiful fruits are melon shaped, up to 40 centimeters in length, with a golden-orange pulp and numerous small black seeds. They are used to a large extent in many tropical countries as a refreshing food, although possessing little actual nutritive value.[1]

The name papaya is said to have been derived from the Carib *ababai*, and has been further altered to the English term papaw. The plant is a native of the Caribbean region, Gulf of Mexico, and South America, and has spread thence to many parts of the world. It was introduced into India early in the seventeenth century, and has been cultivated there ever since. Suitable conditions for its growth exist in many other countries, among which the Hawaiian Islands, Assam, Ceylon, and the Philippine Islands deserve special mention.

Various medicinal uses of papaya have been known for many

[1] Pratt and del Rosario, *This Journal, Sec. A* (1913), **8**, 69.

years. The Caribs have long employed the ripe fruit as a cosmetic, and the remarkable complexions of these people are attributed to the use of the pulp as a skin soap. It is also said to remove freckles, and is frequently used by the natives of Ceylon as a soap to remove stains and to intensify colors, especially black, in washing fabrics. The juice is used in the Antilles as a poultice in the treatment of ulcers, sores, yaws, and other skin diseases, and I found similar application made of it by Singhalese who reported very beneficial results. Antiaphrodisiac properties are frequently ascribed to the papaya by the natives of Ceylon, and a similar superstition is widespread in the Philippines. The well-authenticated action of sliced green fruit in softening meat is known to native cooks in many countries both in Central America and in Asia. Griffith Hughes noted this custom in 1750 when he wrote in his History of Barbadoes, "The juice is of so penetrating a nature, that if the unripe fruit when unpeeled is boiled with the toughest old salt meat, it will soon make it soft and tender." European residents of the tropics are familiar with the important beneficial results of eating ripe papaya. Obstinate cases of dyspepsia and constipation yield readily to the pleasant and simple expediency of including a papaya in the breakfast menu. I have personally known of a sufficient number of such instances to leave no doubt in this respect.

All of these properties are to be attributed to the presence of papain. The latex containing this enzyme is present in all parts of the plant, and exudes from the slightest injury. It is found to the greatest extent in a network of circulatory vessels beneath the surface of unripe fruits, and is collected in commercial quantities by scarifying such papayas. The fresh latex is dried to the consistency of gum and shipped in a crude state, principally to London and Hamburg, whence it is largely re-exported to the United States.

The best quality of papain at the present time is produced in the West Indies, followed by Mexico and Ceylon, although the last produces by far the largest amount of gum. I recently had the opportunity of witnessing Singhalese gather the papaya latex and dry it for shipment. A casual inspection of the primitive methods employed in the Kegalle district, whence the greater part of Ceylon gum is obtained, sufficed to explain why so much unjust criticism has been made regarding the use of papain in medicine and why many physicians have become sceptical of its value as a substitute for pepsin. A brief descrip-

tion of the general procedure from tapping the fruit to export of the gum should be of interest.

Kegalle is situated between Colombo and the Royal Botanic Gardens at Paradeniya, with an annual rainfall of from 190 to 250 centimeters and with soil conditions well adapted to the growth of papayas. Gathering and drying the latex is entirely in the hands of ignorant natives, who are not capable of appreciating the care and cleanliness which should always be employed in dealing with a sensitive material, such as an enzyme. Good results cannot be expected, and it is rather surprising that the final product shows any proteolytic activity, especially as gross adulteration is the rule rather than the exception. The papaya trees are not planted with any degree of regularity, but are found scattered through coconut and areca-palm groves. They receive neither cultivation nor care, but in spite of difficulties continue to bear fruit and support a rather numerous population.

Preparations for gathering latex are very simple, and consist in cutting and forming the leaf sheath of an areca-palm leaf into a shallow basket. A crossbar is tied to the papaya tree at a convenient height, and the basket is hung beneath the unripe fruit, in which slight cuts are made longitudinally, whereupon the milky juice exudes and drops into the basket. The flow is rapid for a few seconds, but becomes slower and slower as the latex coagulates, until it ceases entirely. The jellylike fragments adhering to the fruit are scraped off with a paddle cut from a leafstalk and added to the contents of the basket which are stirred for a few minutes until coagulation takes place (Plate I). It is a common practice to add boiled rice starch at this point for the purpose of increasing the weight and lightening the final color of the gum, the amount of adulterant varying from about 10 to as much as 80 per cent. Other extraneous material, such as clay, bread crumbs, dried fruit, and India rubber latex, are occasionally used.

The juice is now spread out on papers in the sun to dry, three or four days generally being sufficient for the purpose. On several occasions, I noticed papers of partially dried gum exposed to clouds of dust and dirt from near-by thoroughfares. The color gradually darkens as the drying proceeds, until the final product is dark brown to nearly black in the case of straight gum or light brown where large percentages of starch have been added. The former is known to Colombo brokers as No. 1 and the latter as No. 2. Foreign markets demand a light-colored papain, and will not accept No. 1 grade. Pure gum, light in

color and of high activity, could hardly be made by the native process outlined above. An attempt is, therefore, made to meet the requirements of London and Hamburg dealers by blending No. 1 with No. 2. This gives No. 2 mixed (Plate II). The two components may readily be recognized in such a mixture, as the individual lumps are large enough to render separation by hand picking a simple matter. The effect of this blending is to lighten the color considerably, but at the same time very greatly to decrease the activity of the gum. It will be shown later that the light-brown fragments of highly adulterated gum are practically inert, and as this grade frequently comprises from 30 to 50 per cent of an entire shipment it may be seen how seriously the product is injured. Many dealers in Colombo informed me that they were adverse to blending the two grades of papain in this manner, but that dark-colored No. 1 was unsalable and pure light-brown gum could not be made. The latter statement does not correctly represent the situation, as Mexican papain is lighter in color and the West Indian product resembles dried bread crumbs.

Further difficulties have arisen during the past year. Many shipments of Colombo No. 2 mixed have been refused admittance by the United States customs, because adulterated with starch although invoiced as papain. Thus the sale of Ceylon papaya gum has decreased considerably, but various brokers who have dealt in this product for many years informed me that they could readily sell at least a ton per month of high-grade papain provided it were free from adulteration and light colored. Quotations from various drug houses in the United States indicate that properly prepared gum would find a ready market at prices ranging from 11 to 13 pesos per kilogram (2.50 to 3 dollars per pound).

This investigation was undertaken for the purpose of comparing papaya gums made in a variety of ways and, especially, to ascertain whether it was possible to conserve the entire efficiency of fresh latex by employing proper methods for drying. Various means for determining the digestive value of papain have been suggested from time to time, and many firms handling the gum employ arbitrary standards based upon what they consider a satisfactory preparation. Graber[2] uses finely ground steak in dilute hydrochloric acid solution, Rippetoe[3] prefers

[2] *Journ. Ind. & Eng. Chem.* (1911), 3, 919.
[3] Ibid. (1912), 4, 517.

coagulated egg albumen in 0.10 per cent sodium hydroxide solution, while others advocate fibrin, etc. The duration and temperature employed also vary greatly. No systematic investigations have been made that enable one to form a logical opinion regarding the digestive powers of papain; the optimum conditions of temperature, alkalinity, or acidity; the rate of digestion; etc.

It was greatly to be desired that some method for analysis be found which would give accurate results without requiring elaborate apparatus or laborious manipulation and that would not depend upon some sample of papaya gum arbitrarily selected as a standard. Methods depending upon the comparative volumes of undigested material are not trustworthy, and those in which it is necessary to determine the increase in soluble nitrogen during digestion are not only unsatisfactory, but also exceedingly tedious when many analyses have to be made.

The following scheme for assaying papain has given satisfactory results in many hundreds of cases, and may be recommended as simple, rapid, and accurate. It has the advantage of being carried out readily in any laboratory, and gives all the information necessary for determining the quality of the sample.

METHOD FOR THE ANALYSIS OF PAPAIN

Milk, as nearly as possible free from butter fat, is the most satisfactory material to employ as substrate. The various well-known brands of condensed skimmed milk possess reasonably constant composition, and are well suited to the purpose. I employed a 40 per cent solution of sweetened condensed skimmed milk in the analyses recorded in this paper, not only because fresh skimmed milk was not procurable in Manila, but also for the reason that the canned milks keep well and are thus always available.

The enzyme solution was prepared by dissolving 0.75 gram of powdered papain in 150 cubic centimeters of distilled water. Papain is not completely soluble in water, but by warming the mixture for thirty minutes in the thermostat at 40° the active principle is dissolved and upon filtering a clear solution is obtained. Well-prepared gums give a colorless filtrate, which is slightly acid and shows a marked tendency to froth. The digestions were carried out in 150 cubic centimeter Erlenmeyer flasks. The volumes of milk, water, and papain solution used may be seen from Table I.

TABLE I.—*Typical digestion experiment.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.
	cc.	*cc.*	*cc.*	*mg.*
1	25	23	2	10
2	25	21	4	20
3	25	19	6	30
4	25	17	8	40
5	25	15	10	50
6	25	13	12	60
7	25	11	14	70
8	25	9	16	80
9	25	7	18	90
10	25	5	20	100
11	25	25	0	0

The milk and water were always measured into the flasks and mixed by shaking. The enzyme solution was rapidly added from a burette, the contents were well mixed by a few vigorous shakes, and the flasks were at once placed in the thermostat. At the expiration of exactly thirty minutes they were removed in the same order, 20 cubic centimeters of ice water added to each, and the flasks placed in melting ice to stop digestion.

The contents of each flask were then successively washed into a 500 cubic centimeter beaker, sufficient water being used to give approximately 75 cubic centimeters of final volume. The undigested protein was then precipitated by slowly adding 0.5 cubic centimeter of copper sulphate solution (60 grams per liter), followed by 0.5 cubic centimeter of glacial acetic acid, the solution being vigorously stirred during precipitation.

The contents of the beaker were now washed into 100 cubic centimeter measuring cylinders and allowed to stand for a short time to permit the curd to settle, after which they were filtered through 11-centimeter ashless papers, which had been previously numbered, dried at 100°, and weighed. It frequently happens that filtration proceeds very slowly, in which case it is not advisable to wait until all the liquid has passed through, but is better to proceed with the washing. The curd is washed back into the cylinders with distilled water warmed to about 60°, and is thoroughly disintegrated by means of a rubber-tipped stirring rod. The sediment now settles readily, and the solutions filter rapidly. The undigested protein is washed three more times in this manner to remove sugars and soluble digestion products, gentle suction is applied to remove the surplus water,

and the papers are dried to constant weight at 100°. No correction for the amount of papain used is necessary, as it is not precipitated by copper sulphate and acetic acid.

The weight of protein digested by the various amounts of papain may be calculated from the blank in which no enzyme was used. The entire determination with the exception of drying may be made in from three to four hours, and duplicate analyses agree within about 2 per cent. The curves obtained in this manner show at a glance the relative proteolytic power possessed by samples of papain, as well as the rate at which digestion has proceeded with increasing amounts of enzyme. No antiseptic is necessary with such short periods of incubation.

Analyses were carried out in this manner with commercial samples of papain from various sources. A great divergence in activity was encountered, ranging from gum possessing practically no proteolytic power to highly active material. The curves obtained from these data are plotted in fig. 1.

ANALYSES OF PAPAIN

No. 1. Papain from local drug store.—This sample was of unknown origin, and had been obtained from Germany several years previously. It was light colored, and possessed an odor resembling pepsin. A small portion boiled with water gave a positive test for starch with iodine solution. The analysis is shown in Table II.

TABLE II.—*Analysis of papain, sample 1.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,160	0	0.0	
2	25	21	4	20	1,163	0	0.0	
3	25	19	6	30	1,159	0	0.0	
4	25	17	8	40	1,151	4	0.3	0.1
5	25	15	10	50	1,149	6	0.5	0.1
6	25	13	12	60	1,132	22	1.9	0.3
7	25	11	14	70	1,116	39	3.4	0.5
8	25	9	16	80	1,107	48	4.2	0.5
9	25	7	18	90	1,098	57	5.0	0.6
10	25	5	20	100	1,092	63	6.0	0.6

Protein in blank =1,155 milligrams.

Acidity of papain solution as HCl =0.005 per cent.

The sample was practically inert, although it retailed at 1 peso (50 cents) per 20 grams.

No. 2. Ceylon papain. Grade 2.—I obtained this sample from the warehouse of a prominent broker in Colombo, who informed me that it represented the usual quality of the light-colored, highly adulterated grade. The analysis is shown in Table III.

TABLE III.—*Analysis of second-grade Ceylon papain, sample 2.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,119	1	0.1	0.1
2	25	21	4	20	1,111	9	0.8	0.4
3	25	19	6	30	1,120	0		
4	25	17	8	40	1,121	0		
5	25	15	10	50	1,104	16	1.4	0.3
6	25	13	12	60	1,069	51	4.6	0.8
7	25	11	14	70	1,093	27	2.4	0.4
8	25	9	16	80	1,086	34	3.0	0.4
9	25	7	18	90	1,101	19	1.7	0.2
10	25	5	20	100	1,107	13	1.2	0.1

Protein in blank = 1,120 milligrams.
Starch present in large amounts.
Practically inert.

No. 3. Ceylon papain. Grade 1.—This sample was from the same source as the preceding. It was chocolate colored and nonfriable. The analysis is shown in Table IV.

TABLE IV.—*Analysis of grade 1, Ceylon papain, sample 3.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg*	*Per cent*	
1	25	23	2	10	1,064	56	5.0	5.6
2	25	21	4	20	996	124	11.1	6.2
3	25	19	6	30	890	230	20.6	7.6
4	25	17	8	40	885	235	21.0	5.8
5	25	15	10	50	858	262	23.4	5.2
6	25	13	12	60	827	293	26.2	4.9
7	25	11	14	70	789	331	29.6	4.7
8	25	9	16	80	748	372	33.2	4.6
9	25	7	18	90	720	400	35.7	4.4
10	25	5	20	100	674	446	39.8	4.0

Protein in blank = 1,120 milligrams.
Starch present.
Acidity of papain solution as HCl = 0.008 per cent.
The activity is not high, and the ratio is very low even with small amounts of gum

No. 4. Ceylon papain.—I obtained this sample from another prominent dealer in Colombo. It closely resembled the preceding in appearance, and was considered as unadulterated. The analysis is shown in Table V.

TABLE V.—*Analysis of Ceylon papain, sample 4.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,033	96	8.5	9.6
2	25	21	4	20	943	186	16.5	9.3
3	25	19	6	30	877	252	22.4	8.4
4	25	17	8	40	802	327	29.0	8.2
5	25	15	10	50	759	370	32.8	7.4
6	25	13	12	60	717	412	36.5	6.9
7	25	11	14	70	688	441	39.1	6.3
8	25	9	16	80	645	484	42.8	6.1
9	25	7	18	90	612	517	45.9	5.7
10	25	5	20	100	589	540	48.0	5.4

Protein in blank = 1,129 milligrams.
Starch absent.
Acidity of papain solution as HCl = 0.004 per cent.

No. 5. Ceylon papain.—This sample was from the same source as No. 4 and is similar in appearance, but it contains starch as adulterant. The analysis is shown in Tables VI and VII.

TABLE VI.—*Analysis of Ceylon papain, sample 5.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,156	57	4.7	5.7
2	25	21	4	20	1,112	101	8.3	5.0
3	25	19	6	30	1,087	126	10.4	4.2
4	25	17	8	40	1,035	178	14.7	4.4
5	25	15	10	50	995	218	18.0	4.4
6	25	13	12	60	933	280	23.1	4.6
7	25	11	14	70	937	276	22.8	3.9
8	25	9	16	80	878	335	27.6	4.2
9	25	7	18	90	850	363	29.9	4.0
10	25	5	20	100	808	405	33.3	3.8

Protein in blank = 1,213 milligrams.
Starch present.
Acidity of papain solution as HCl = 0.003 per cent.

TABLE VII.—*Duplicate analysis of Ceylon papain, sample 5.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested	Protein digested.	Protein digested	Parts of protein digested by 1 part papain
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,1[illegible]	70	[illegible]	7.0
2	25	21	4	20	1,1[illegible]	100	[illegible]	[illegible]
3	25	19	6	30	1,112	116	9.5	3.8
4	25	17	8	40	1,036	152	13.7	4.[illegible]
5	25	15	10	50	927	221	18.8	4.[illegible]
6	25	13	12	60	931	[illegible]	20.[illegible]	4.1
7	25	11	14	70	[illegible]	[illegible]	21.[illegible]	[illegible]
8	25	9	16	80	941	[illegible]	23.1	3.6
9	25	7	18	90	886	[illegible]	27.[illegible]	3.7
10	25	5	20	100	841	417	34.0	[illegible]

This is a duplicate analysis of sample 5, and is included to show how close agreement may be expected when dealing with low-grade gums.

No. 6. Ceylon papain.—This sample was obtained from Mead Johnson and Company, Jersey City, U. S. A. It is considerably lighter in color than the preceding, being approximately a mean between grades 1 and 2. The analysis is shown in Table VIII.

TABLE VIII.—*Analysis of Ceylon papain, sample 6.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	941	220	19.0	22.0
2	25	21	4	20	790	371	31.9	18.6
3	25	19	6	30	697	464	40.0	15.4
4	25	17	8	40	614	547	47.2	13.7
5	25	15	10	50	532	629	54.3	12.6
6	25	13	12	60	482	679	58.5	11.3
7	25	11	14	70	451	710	61.3	10.1
8	25	9	16	80	412	749	64.5	9.4
9	25	7	18	90	383	778	67.1	7.4
10	25	5	20	100	365	796	68.6	6.9

Protein in blank = 1,161 milligrams.
Starch absent.
Acidity of papain solution as HCl = 0.007 per cent.
Mead Johnson & Co. states that this is an unusually light-colored specimen of Ceylon gum.

No. 7. Ceylon papain.—This sample was obtained from Mead Johnson and Company. It consists of both dark- and light-colored fragments, and may be classified as grade 2 mixed. The results of the analysis are shown in Table IX.

TABLE IX.—*Analysis of Ceylon papain, sample 7.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,179	...		
2	25	21	4	20	1,144	35	3.0	1.8
3	25	19	6	30	1,156	23	2.0	0.7
4	25	17	8	40	1,129	50	4.2	1.2
5	25	15	10	50	1,106	73	6.2	1.4
6	25	13	12	60	1,134	45	3.8	0.8
7	25	11	14	70	1,097	82	7.0	1.2
8	25	9	16	80	1,100	79	6.7	1.0
9	25	7	18	90	1,073	106	9.0	1.2
10	25	5	20	100	1,036	143	12.2	1.2

Protein in blank=1,179 milligrams.
Starch present in large amount.
Acidity of papain solution as HCl=0.001 per cent.
Regarding this sample Mead Johnson & Co. states that it is a good specimen of the product usually handled by drug brokers. The above analysis shows how little value it actually possesses.

No. 8. Mexican papain.—This sample was obtained from Mead Johnson and Company. It was approximately the color of sample 6, and showed a comparatively uniform composition. The results of the analysis are shown in Table X.

TABLE X.—*Analysis of Mexican papain, sample 8.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,090	129	6.5	12.9
2	25	21	4	20	1,009	210	17.2	10.5
3	25	19	6	30	956	263	21.6	8.8
4	25	17	8	40	889	330	27.1	8.3
5	25	15	10	50	804	415	34.0	8.3
6	25	13	12	60	772	447	36.7	7.5
7	25	11	14	70	734	485	39.8	6.9
8	25	9	16	80	698	521	42.7	6.5
9	25	7	18	90	660	559	45.8	6.2
10	25	5	20	100	645	574	47.1	5.7

Protein in blank=1,219 milligrams.
Starch absent.
Acidity of papain solution as HCl=0.005 per cent.
Mead Johnson & Co. states that this is unusually dark colored for Mexican gum, which should more resemble the West Indian product.

No. 9. West Indian papain. This sample was ob[illegible] Mead Johnson and Company. It [illegible] friable, and of uniform appearance. The analysis is given in Table XI.

TABLE XI. [illegible]

No. of flask	Milk	Water	Papain solution	Papain	[illegible]	[illegible]	[illegible]	Units of protein digested by 1 gram papain
	cc.	cc.	cc.	[illegible]	[illegible]	[illegible]	[illegible]	
1	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
5	[illegible]	[illegible]	10	[illegible]	[illegible]		[illegible]	[illegible]
6	25	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
7	25	11	[illegible]	[illegible]	[illegible]			[illegible]
8	[illegible]	[illegible]	16	[illegible]			[illegible]	11
9	[illegible]	[illegible]	18	[illegible]	[illegible]	[illegible]	[illegible]	10
10	25	[illegible]	[illegible]	100	[illegible]	[illegible]	[illegible]	[illegible]

Protein in blank, 1,215 milligram.
Starch absent.
Acidity of papain solution [illegible] HCl [illegible] per cent.
Mead Johnson & Co. [illegible] states that it is [illegible] West Indian [illegible] and this view is clearly substantiated by the above analysis.

The results of the above analyses are plotted in fig. 1, where the various curves show not only the percentage of total protein digested by increasing amounts of papain, but also give graphically a clear idea of the marked differences existing in the proteolytic activity of the samples, whose numbers are given. Thus, the amount of milk protein digested in thirty minutes at 40° by 1 milligram of West Indian papain is seen to exceed that digested under similar conditions by 100 milligrams of sample 7, representing ordinary Ceylon papain.

PREPARATION OF PAPAIN

Various methods for converting fresh latex into dry papain were investigated, in order to ascertain the extent of deterioration during drying and the possibility of preparing papain commercially which would exceed the West Indian product in its proteolytic activity. The fresh latex for this work was obtained under my personal supervision.

Green fruits were scarified with steel knives in the usual

manner, and the juice was collected in porcelain evaporating dishes. The entire collection, amounting to approximately 0.5 kilogram, was thoroughly mixed to insure uniform composition, using a bone spatula, and was divided into various portions

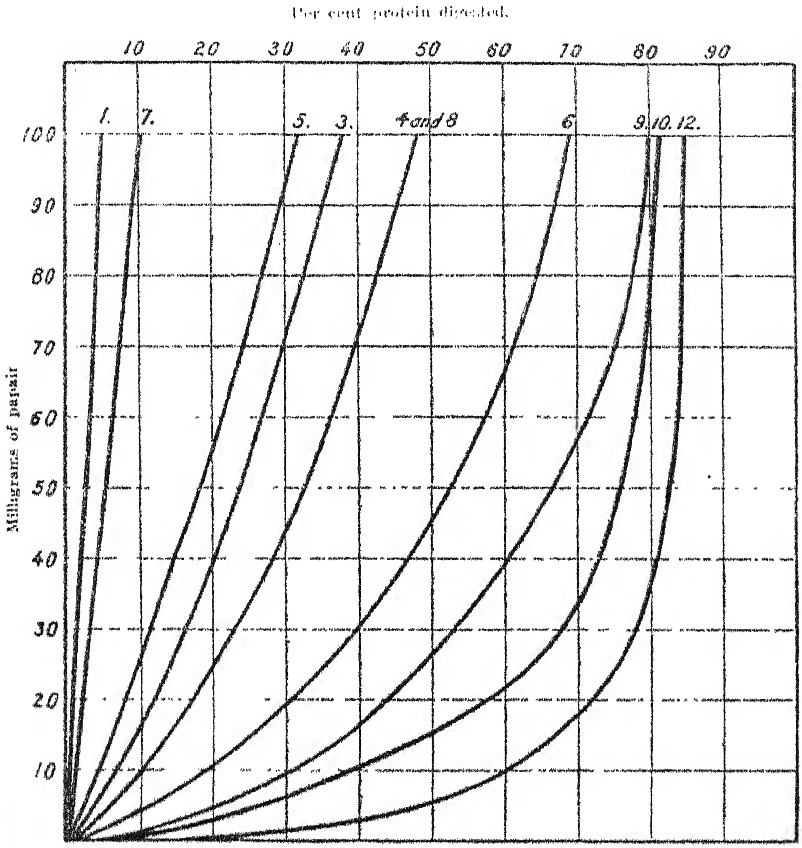


FIG. 1. *Curve 1.* Papain from local drug store. *Curve 3.* Ceylon papain, sample 3. *Curve 4.* Ceylon papain, sample 4. *Curve 5.* Ceylon papain, sample 5. *Curve 6.* Ceylon papain, sample 6. *Curve 7.* Ceylon papain, sample 7. *Curve 8.* Mexican papain, sample 8. *Curve 9.* West Indian papain, sample 9. *Curve 10.* Fresh papaya latex, sample 10. *Curve 12.* Papain by alcohol precipitation, sample 12.

which were treated in different ways. The activity of the original latex designated No. 10 was obtained by analysis in the above manner, the weight of latex used being computed to dry papain. The results of the analysis are shown in Table XII.

TABLE XII.—*Analysis of fresh papaya latex, sample 10.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Units of protein digested by 1 mg. papain.
	cc.	cc.	cc.	mg.	mg.	mg.	Per cent.	
1	25	23	2	10	[illegible]	[illegible]	[illegible]	[illegible]
2	25	21	4	20	[illegible]	[illegible]	[illegible]	[illegible]
3	25	19	6	30	[illegible]	[illegible]	71.0	27.1
4	25	17	8	40	[illegible]	[illegible]	[illegible]	21.2
5	25	15	10	50	[illegible]	[illegible]	[illegible]	17.7
6	25	13	12	60	[illegible]	[illegible]	[illegible]	15.1
7	25	11	14	70	[illegible]	[illegible]	[illegible]	13.1
8	25	9	16	80	[illegible]	[illegible]	[illegible]	11.7
9	25	7	18	90	[illegible]	[illegible]	[illegible]	10.5
10	25	5	20	100	[illegible]	[illegible]	[illegible]	9.5

Protein in blank = 1,160 milligrams.
Acidity of enzyme solution as HCl = 0.006 per cent.

The relationship between enzyme and percentage of protein digested in thirty minutes at 40° is plotted as curve 10 in fig. 1. It is evident that the fresh latex is considerably more active than dried papain from the Antilles, although both preparations are capable of digesting approximately the same amount of milk protein with relatively large amounts of enzyme present. The curve for fresh latex shows a rapid increase in digestion with increasing amounts of papain up to about 20 milligrams corresponding to 58 per cent digestion of the total protein content, while the West Indian papain gives only 41 per cent digestion at this concentration.

A portion of the fresh latex was spread out in a porcelain dish to form a thin layer and was sundried. It was frequently stirred, and the gummy lumps were sliced to facilitate the rapid evaporation of moisture. The color darkened slightly, and approximated that shown by the West Indian papain. The product designated No. 11 was readily friable when thoroughly dry, and gave the analysis shown in Table XIII.

The results of this analysis are not plotted, as the curve closely approximates that given by fresh latex. The central portion shows somewhat less digestion, the maximum divergence being about 3 per cent with 40 milligrams of papain. It thus appears that sundried papain is not necessarily less active than the fresh latex, but in this case it must be remembered that considerable care was given the sample to insure rapid drying, the exclusion of dust, etc. It was also dried promptly after collection. This is very important, as fermentation takes place

TABLE XIII.—*Analysis of sundried Philippine papain, sample 11.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	704	451	39.4	45.4
2	25	21	4	20	510	645	55.8	32.3
3	25	19	6	30	404	751	65.0	25.0
4	25	17	8	40	347	808	70.0	20.2
5	25	15	10	50	308	847	73.5	16.9
6	25	13	12	60	278	877	76.0	14.6
7	25	11	14	70	259	896	77.7	12.8
8	25	9	16	80	249	906	78.5	11.3
9	25	7	18	90	235	920	79.6	10.2
10	25	5	20	100	203	952	82.5	9.5

Protein in blank = 1,165 milligrams.
Acidity of papain solution as HCl = 0.008 per cent.

rapidly in papaya latex with the production of nauseating odors and destruction of the enzyme.

Small portions of the fresh latex were dried rapidly in vacuo over sulphuric acid. The resulting papain was a light cream color, was easily friable, and upon analysis showed little if any difference in activity from the original. The chief advantages resulting from drying in this manner are the shortness of the time required, lighter color, and more porous nature of the resulting papain. Its successful application on a large scale would necessitate special machinery, whereby the latex might be thoroughly stirred during drying. Further difficulties would arise from the gummy consistency of the partially dried product and the necessity of avoiding contact with metals that cause darkening of the color.

Many enzymes may be purified and separated from extraneous material by precipitation with alcohol. This method is applicable to papaya latex, and gives excellent results provided the action of the alcohol is limited to as short a time as possible.

Twenty grams of the fresh latex were well mixed with 100 cubic centimeters of 95 per cent alcohol. A gummy white coagulum was thrown down that was readily collected in a ball. The alcohol was poured off and replaced with 50 cubic centimeters of the same strength. The papain readily crumbled to a fine powder during the second treatment with alcohol. It was filtered with suction and washed twice with ether to remove a semisolid yellow wax and to facilitate drying. The washed

papain was dried in vacuo, giving a perfectly white powder with a faint characteristic odor; yield, 3 grams. The time required from latex to dry papain was about twenty minutes. An analysis of this product designated No. 12 is shown in Table XIV.

TABLE XIV.—*Analysis of Philippine papain, sample 12.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	451	722	61.5	72.2
2	25	21	4	20	330	843	71.8	42.1
3	25	19	6	30	266	907	77.3	30.2
4	25	17	8	40	234	939	80.0	23.5
5	25	15	10	50	224	949	81.0	19.0
6	25	13	12	60	196	977	83.2	16.3
7	25	11	14	70	183	990	84.5	14.1
8	25	9	16	80	185	988	84.0	12.3
9	25	7	18	90	182	991	84.5	11.0
10	25	5	20	100	175	998	85.3	10.0

Protein in blank=1,173 milligrams.
Acidity of papain solution as HCl=0.004 per cent.

The results of this analysis are plotted in fig. 1 as curve 12. It may be seen that this sample of papain is very active, 10 milligrams being capable of digesting as much milk protein as 22 milligrams of the Philippine sundried papain or 40 milligrams of the West Indian product. This probably represents the most active papain that could be prepared commercially. Its manufacture by this method would necessitate a still for recovering the waste alcohol. The use of ether would hardly be practical in tropical countries, but could be employed by drug firms using papain, if desirable.

Papain prepared in this manner is nearly soluble in water, giving an opalescent solution with small flocks of white insoluble material. The solution rapidly curdles milk, with the formation of a fine curd that quickly redissolves. This property of papain should make it of great value in preparing milk for infant feeding, as the formation of heavy indigestible curds in the stomach may thus be avoided.

RATE OF DIGESTION

All of the preceding digestions were carried out at 40° for a period of thirty minutes. The following experiment was made to determine the rate at which milk protein is digested by pa-

pain. All of the flasks contained the same amounts of milk, water, and enzyme solution, but were maintained at 40° for varying lengths of time before precipitation. The results of this series are shown in Table XV. The papain used was sample 6 from Ceylon.

TABLE XV.—*Rate of digestion of milk protein.*

No. of flask.	Time of digestion.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	Mins.	*mg.*	*mg.*	*Per cent.*	
1	10	862	281	24.7	11.2
2	20	816	327	28.6	13.1
3	30	783	360	31.5	14.4
4	40	760	383	33.5	15.3
5	50	741	402	35.1	16.0
6	60	714	429	37.5	17.0
7	70	703	440	38.4	17.6
8	80	702	441	38.5	17.6
9	90	708	435	38.1	17.4
10	100	664	479	41.8	19.1
11	110	685	458	40.1	18.0
12	120	675	468	40.9	18.7
13	130	681	462	40.3	18.5
14	140	668	475	41.6	19.0
15	150	658	485	42.4	19.4

Protein in blank = 1,143 milligrams.

Each flask contained 25 cubic centimeters of milk, 20 cubic centimeters of water, and 5 cubic centimeters of enzyme solution equivalent to 25 milligrams of papain.

These results are plotted in fig. 2. An inspection of this curve shows that digestion proceeded rapidly during the first ten minutes and practically reached its maximum within an hour. The nature of the protein and conditions of solution, concentration, etc. would affect the equilibrium to a greater or less extent, so that this period of digestion must not be taken as applying to some other substrate, such as beef.

DIGESTION UNDER VARIOUS CONDITIONS

The literature of papain contains many conflicting statements regarding the conditions suitable for digestion. Some authors claim that the enzyme acts in neutral, alkaline, or acid solution; others, that one or the other is best suited for proteolytic activity. The question is important in its bearing upon the use of papain as a medicinal agent and interesting in comparing papain with other enzymes, such as pepsin and trypsin.

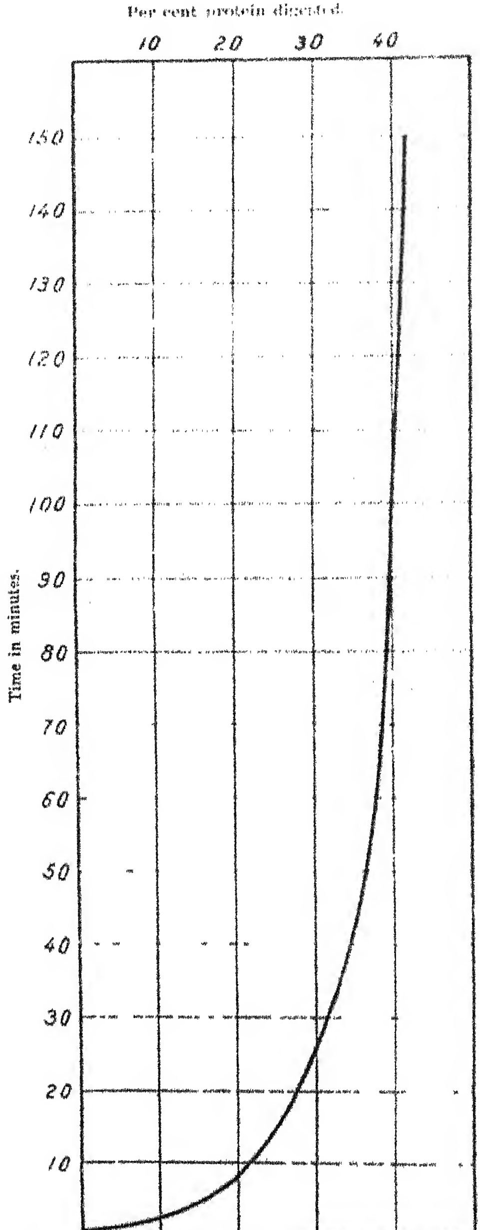


FIG. 2. Rate of digestion of milk protein by papain.

PAPAIN DIGESTION IN ACID SOLUTION

The following experiments were made to determine the effect of hydrochloric acid on the digestion of milk protein. The digestions were carried out in the usual manner for thirty minutes at 40°. The results are shown in Table XVI.

TABLE XVI.—*Papain digestion of milk protein in acid solution.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Hydrochloric acid solution.	Hydrochloric acid.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*cc.*	*Per cent.*	*mg.*	*mg.*	*Per cent.*	
1	25	15	10	50	0	0.00	651	505	43.7	10.1
2	25	14	10	50	1	0.02	671	485	42.0	9.7
3	25	13	10	50	2	0.04	670	486	42.0	9.7
4	25	12	10	50	3	0.06	719	437	37.8	8.7
5	25	11	10	50	4	0.08	750	406	35.1	8.1
6	25	10	10	50	5	0.10	838	318	27.6	6.4
7	25	9	10	50	6	0.12	946	210	18.2	4.2
8	25	8	10	50	7	0.14	982	174	15.1	3.5
9	25	7	10	50	8	0.16	998	158	13.7	3.2
10	25	6	10	50	9	0.18	1,000	156	13.5	3.1
11	25	5	10	50	10	0.20	1,003	153	13.2	3.1

Protein in blank = 1,156 milligrams.

TABLE XVII.—*Papain digestion of milk protein in acid solution.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Hydrochloric acid solution.	Hydrochloric acid.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*cc.*	*Per cent.*	*mg.*	*mg.*	*Per cent.*	
1	25	20	5	25	0	0.00	951	250	20.8	10.0
2	25	19	5	25	1	0.02	951	250	20.8	10.0
3	25	18	5	25	2	0.04	974	227	18.9	9.1
4	25	17	5	25	3	0.06	989	212	17.7	8.5
5	25	16	5	25	4	0.08	1,004	197	16.4	7.9
6	25	15	5	25	5	0.10	1,060	141	11.8	5.6
7	25	14	5	25	6	0.12	1,110	91	7.6	3.6
8	25	13	5	25	7	0.14	1,115	86	7.2	3.4
9	25	12	5	25	8	0.16	1,123	78	6.5	3.1
10	25	11	5	25	9	0.18	1,136	65	5.4	2.6
11	25	10	5	25	10	0.20	1,138	63	5.3	2.5

Protein in blank = 1,201 milligrams.

The results of this experiment are plotted as curve 1 in fig. 3. This curve shows that amounts of hydrochloric acid up to 0.06 per cent have only a slight retarding action on the digestion of milk protein. Increasing amounts from 0.06 to 0.13 per cent acid very greatly reduce the activity of the enzyme,

although any further increase up to 0.20 per cent causes practically no change. A sharply defined range of acidity thus reduces the digestion to one-half its former value. One more example

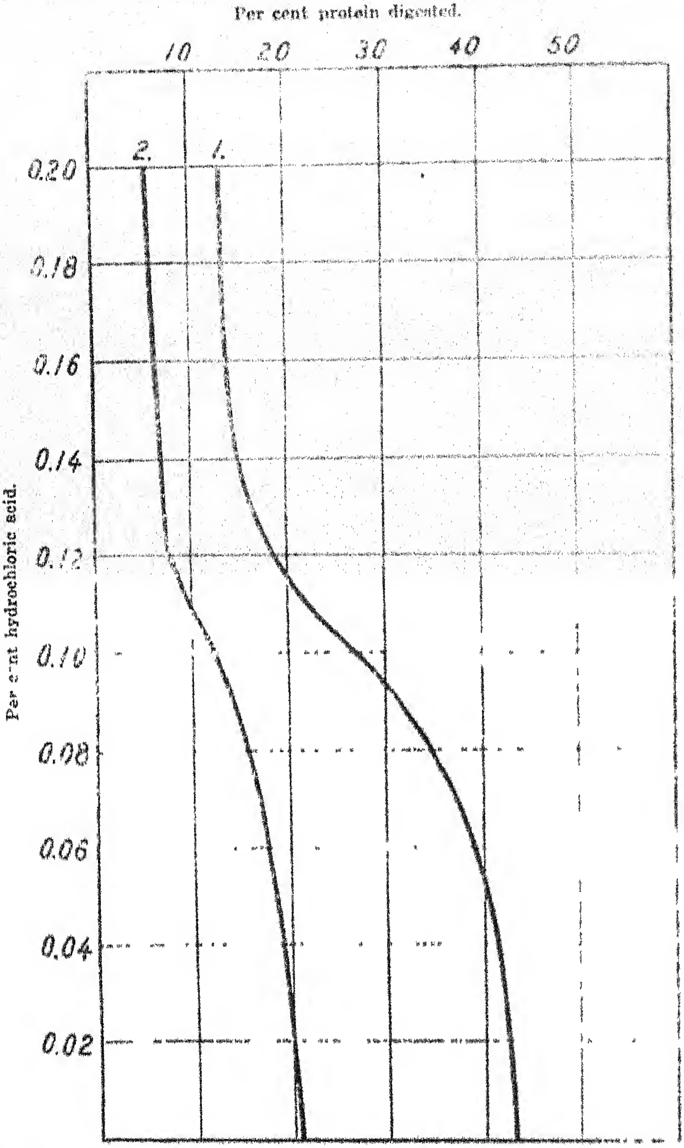


FIG. 3. Digestion in hydrochloric acid solution. *Curve 1.* With 50 milligrams of papain *Curve 2.* With 25 milligrams of papain

of digestions under similar conditions, but with a less amount of papain, will serve to show the same peculiar effect.

The results are plotted as curve 2 in fig. 3. It will be noticed that the two curves are entirely analogous and that the percent-

age of protein digested by 25 milligrams of papain is almost exactly half that found with 50 milligrams at corresponding points on the curves. In all cases, the mineral acid was neutralized by an equivalent amount of sodium hydroxide solution immediately before precipitating with copper sulphate and acetic acid. Otherwise, milky solutions are encountered that will not permit filtration.

The peculiar transition point in these curves was thought to indicate the appearance of uncombined hydrochloric acid, but such is not the case. A similar series was prepared for the purpose of determining free acid by titration, using Topfer's reagent (dimethylamidoazobenzol) as indicator. None of the flasks showed the presence of free acid. The milk in the flasks containing 0.02 per cent acid was not coagulated, that with 0.04 and 0.06 per cent showed slight coagulation, while the remainder was coagulated.

In as much as the enzyme solution had been added after acidification, there was a possibility that the papain acted only as the surface of curds thus formed and that the results, therefore, did not represent the true rate of digestion. This possibility was avoided by adding the enzyme solution to the milk and water before acidifying. All the solutions were maintained at 0° to prevent digestion before the addition of acid. It was impossible to start the digestions as promptly in this manner as in previous cases. The time, therefore, was extended to ninety minutes to compensate for irregularity at the beginning and to insure equilibrium. Papain 6 was used. The results are found in Table XVIII.

TABLE XVIII.—*Papain digestion of milk protein in acid solution.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Hydrochloric acid solution.	Hydrochloric acid.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*cc.*	*Per cent.*	*mg.*	*mg.*	*Per cent.*	
1	25	15	10	50	0	0.60	620	522	45.7	110.4
2	25	14	10	50	1	0.02	617	525	46.0	10.5
3	25	13	10	50	2	0.04	640	502	44.0	0.0
4	25	12	10	50	3	0.06	687	455	39.8	9.1
5	25	11	10	50	4	0.08	747	395	34.5	7.9
6	25	10	10	50	5	0.10	820	322	28.2	6.4
7	25	9	10	50	6	0.12	937	205	18.0	4.1
8	25	8	10	50	7	0.14	987	155	13.6	3.1
9	25	7	10	50	8	0.16	982	160	14.0	3.2
10	25	6	10	50	9	0.18	1,001	141	12.4	2.8
11	25	5	10	50	10	0.20	1,005	137	12.0	2.7

Protein in blank=1,142 milligrams.

The results are practically identical with those given in Table XVI, and show that no different effect is obtained by adding the enzyme solution before coagulation.

Digestion experiments were carried out in solutions containing sodium bicarbonate in amounts ranging from 0.0 to 0.2 per cent. The presence of this alkali had no effect on the digestion of milk protein. Similar negative results were obtained with concentrations of sodium chloride varying from 0.10 to 1.0 per cent, although both of these are said to accelerate the digestion of beef by papain.[4]

HYDROCYANIC ACID

Much of the early work that is recorded in the literature of papain must be questioned, because hydrocyanic acid was employed as the antiseptic. It is now known that papain digestion of protein proceeds more rapidly and more completely in the presence of this acid than when toluol or other antiseptic is used. Vines[5] stated that his experiments "strikingly demonstrate the remarkably favourable effect of the presence of HCN upon the proteolytic activity of papain." Mendel and Blood[6] have confirmed this statement in an extended series of experiments with commercial samples of papain, and state that the

> accelerating effect [of HCN] is not limited to the hydrolysis of peptone but is also shown in the digestion of raw and coagulated egg-white, fibrin, edestin, and excelsin whether one take as the gauge of digestion the appearance of tryptophane, leucine and tyrosin, the conversion into products not precipitated by hot trichloracetic acid or the rate of solution of insoluble protein.

No satisfactory explanation of the action of hydrocyanic acid has been advanced. The following series was run with increasing amounts of acid to determine its effect on the digestion of milk protein by pure papain. The enzyme was prepared by the alcohol-precipitation method, and was very active. The data and results are shown in Table XIX.

It may be seen from this table that hydrocyanic acid also increased the percentage of milk protein digested by papain. The ratio increased by about 2 units, although no positive color test with bromine water for tryptophane could be obtained. The presence of 0.02 per cent acid was sufficient to give the maximum effect under these conditions, higher concentrations causing no further increase.

[4] Private communication from L. D. Johnson.
[5] *Ann. Bot.* (1903), 17, 606.
[6] *Journ. Biol. Chem.* (1910), 8, 182.

TABLE XIX.—*Effect of hydrocyanic acid on papain digestion of milk protein.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Hydrocyanic acid solution.	Hydrocyanic acid.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*cc.*	*Per cent.*	*mg.*	*mg.*	*Per cent.*	
1	25	15	10	50	0	0.00	270	881	76.5	17.6
2	25	14	10	50	1	0.02	197	954	82.8	19.1
3	25	13	10	50	2	0.04	178	973	84.5	19.5
4	25	12	10	50	3	0.06	196	955	83.0	19.1
5	25	11	10	50	4	0.08	200	951	82.6	19.0
6	25	10	10	50	5	0.10	189	962	83.5	19.2
7	25	9	10	50	6	0.12	181	970	84.2	19.4
8	25	8	10	50	7	0.14	179	972	84.4	19.4
9	25	7	10	50	8	0.16	178	973	84.4	19.4
10	25	6	10	50	9	0.18	179	972	84.4	19.4
11	25	5	10	50	10	0.20	187	964	83.7	19.3

Protein in blank = 1,151 milligrams.
Time of digestion, thirty minutes.
Temperature, 40°.

The remarkable effect of hydrocyanic acid was not studied in detail, as it has no bearing on the actual use or preparation of papain. However, the difficulty of obtaining samples of pure papain of known history made it worth while to examine the digestion of peptone under these conditions.

THE FORMATION OF TRYPTOPHANE FROM WITTE'S PEPTONE

The following mixtures were prepared and incubated at 40°.

Mixture 1.

	cc.
Peptone, 5 per cent	20.0
Papain, 1 per cent	20.0
Water, distilled	20.0
Toluol	0.5

Mixture 2.

	cc.
Peptone, 5 per cent	20.0
Papain, 1 per cent	20.0
Hydrocyanic acid solution, 0.1 per cent	20.0
Toluol	0.5

Mixture 3, control.

	cc.
Peptone, 5 per cent	20.0
Hydrocyanic acid solution, 0.1 per cent	20.0
Water, distilled	20.0
Toluol	0.5

Portions were removed and tested with bromine water for tryptophane. Nos. 1 and 3 gave no color, while No. 2 gave a pronounced purple after twenty-four hours' incubation. These results are in accord with the data given by Mendel and Blood,[7] working with commercial material.

DIGESTION AT VARIOUS TEMPERATURES

Digestions of milk protein were carried out in the usual manner at temperatures ranging from 0° to 70° to determine the activity of papain under these conditions. The papain used in these determinations was prepared by the alcohol precipitation method, and was very active. All digestions were for thirty-minute periods. That at 0° was carried out with all flasks surrounded by finely cracked ice, contained in a well-insulated thermostat. The temperature was not allowed to rise until after the final precipitation with copper sulphate and acetic acid. The analysis is shown in Table XX.

TABLE XX.—*Papain digestion of milk protein at 0°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	1,102	38	3.3	3.8
2	25	21	4	20	1,048	92	8.1	4.6
3	25	19	6	30	993	147	12.9	4.9
4	25	17	8	40	987	153	13.4	3.8
5	25	15	10	50	922	218	19.1	4.4
6	25	13	12	60	861	279	24.4	4.7
7	25	11	14	70	827	313	27.4	4.8
8	25	9	16	80	817	323	28.4	4.0
9	25	7	18	90	789	351	30.8	3.9
10	25	5	20	100	756	384	33.7	3.4

Protein in blank = 1,140 milligrams.

Papain shows a remarkable activity at low temperatures, as may be seen from the curve in fig. 4 plotted from the above analysis.

The results of a series of digestions run at 10° are shown in Table XXI.

[7] Loc. cit.

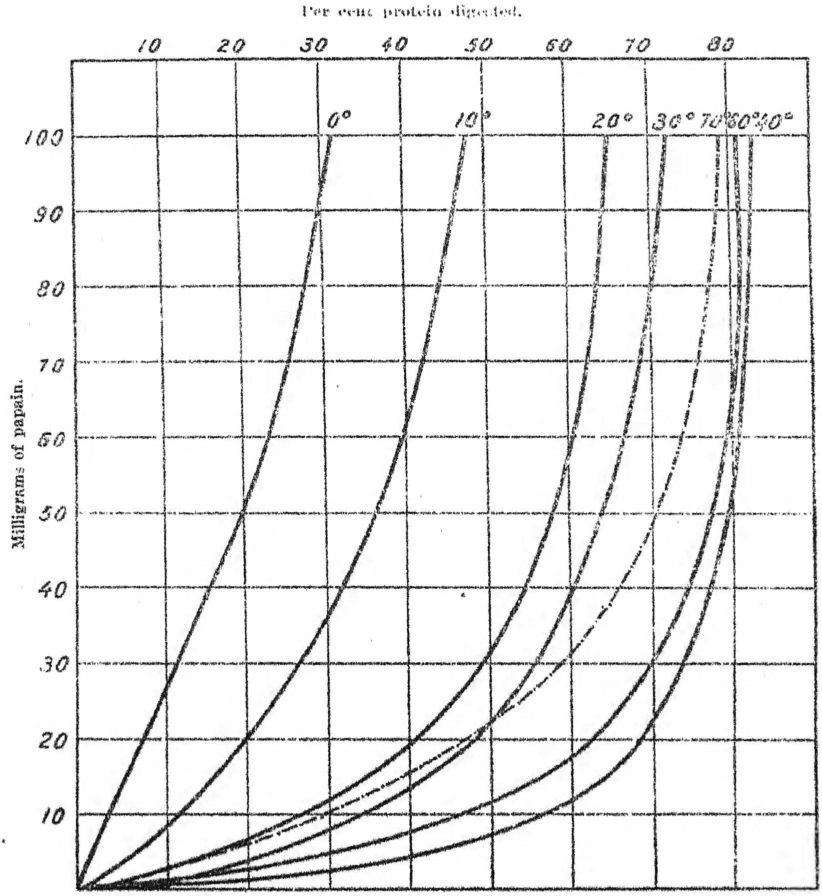


FIG. 4. Digestions at temperatures from 0° to 70°.

TABLE XXI.—*Papain digestion of milk protein at [illegible].*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	985	155	13.6	15.5
2	25	21	4	20	903	237	20.8	11.9
3	25	19	6	30	827	313	27.4	10.4
4	25	17	8	40	770	370	32.4	9.3
5	25	15	10	50	723	417	36.6	8.3
6	25	13	12	60	685	455	39.9	7.6
7	25	11	14	70	652	488	42.8	7.0
8	25	9	16	80	631	509	44.6	6.4
9	25	7	18	90	605	535	47.0	5.9
10	25	5	20	100	593	547	48.0	5.5

Protein in blank = 1,140 milligrams.

The results of a series of digestions run at 20° are shown in Table XXII.

TABLE XXII.—*Papain digestion of milk protein at 20°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	800	326	29.0	32.6
2	25	21	4	20	648	478	42.5	23.9
3	25	19	6	30	576	550	48.9	18.3
4	25	17	8	40	501	625	55.6	15.6
5	25	15	10	50	469	657	58.4	13.2
6	25	13	12	60	456	670	59.5	11.2
7	25	11	14	70	434	692	61.5	9.9
8	25	9	16	80	412	714	63.4	8.9
9	25	7	18	90	395	731	65.0	8.1
10	25	5	20	100	382	744	66.0	7.4

Protein in blank = 1,126 milligrams.

The results of a series of digestions run at 30° are shown in Table XXIII.

The results of a series of digestions run at 40° are shown in Table XXIV.

The results of a series of digestions run at 50° are shown in Table XXV.

The values obtained closely approximate those given in Table XXIV. There appears to be very little difference in the rate of digestion in the neighborhood of 40° to 50°.

TABLE XXIII.—*Papain digestion of milk protein at 30°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	740	423	36.4	42.3
2	25	21	1	20	583	580	49.8	29.0
3	25	19	6	30	501	662	56.9	22.1
4	25	17	8	40	443	720	61.8	18.0
5	25	15	10	50	409	754	64.8	15.1
6	25	13	12	60	385	778	66.8	13.0
7	25	11	14	70	365	798	68.7	11.4
8	25	9	16	80	340	823	70.6	10.3
9	25	7	18	90	302	861	74.0	9.6
10	25	5	20	100	294	869	74.8	8.7

Protein in blank=1,163 milligrams.

TABLE XXIV.—*Papain digestion of milk protein at 40°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	483	715	59.6	71.5
2	25	21	4	20	358	840	70.0	42.0
3	25	19	6	30	298	900	75.0	30.0
4	25	17	8	40	275	923	77.0	23.1
5	25	15	10	50	254	944	78.7	18.9
6	25	13	12	60	230	968	80.7	16.1
7	25	11	14	70	223	975	81.3	13.9
8	25	9	16	80	209	989	82.6	12.4
9	25	7	18	90	208	990	82.6	11.0
10	25	5	20	100	202	996	83.0	10.0

Protein in blank=1,126 milligrams.

TABLE XXV.—*Papain digestion of milk protein at 50°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	546	583	51.7	58.3
2	25	21	4	20	367	762	67.7	38.1
3	25	19	6	30	293	836	74.0	27.9
4	25	17	8	40	249	880	78.0	22.0
5	25	15	10	50	233	896	79.5	17.9
6	25	13	12	60	202	927	82.1	15.4
7	25	11	14	70	199	930	82.5	13.3
8	25	9	16	80	191	938	83.0	11.7
9	25	7	18	90	184	945	83.8	10.5
10	25	5	20	100	180	949	84.2	9.5

Protein in blank=1,129 milligrams.

The results of a series of digestions run at 60° are shown in Table XXVI.

TABLE XXVI.—*Papain digestion of milk protein at 60°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	[illegible]	[illegible]	[illegible]	[illegible]
2	25	21	4	20	421	[illegible]	[illegible]	[illegible]
3	25	19	6	30	[illegible]	[illegible]	[illegible]	[illegible]
4	25	17	8	40	[illegible]	[illegible]	[illegible]	[illegible]
5	25	15	10	50	[illegible]	[illegible]	[illegible]	[illegible]
6	25	13	12	60	[illegible]	[illegible]	[illegible]	[illegible]
7	25	11	14	70	[illegible]	[illegible]	[illegible]	[illegible]
8	25	9	16	80	[illegible]	[illegible]	[illegible]	[illegible]
9	25	7	18	90	211	[illegible]	[illegible]	10.5
10	25	5	20	100	[illegible]	[illegible]	[illegible]	[illegible]

Protein in blank = 1,164 milligrams.

These results show that the optimum temperature has been exceeded, as corresponding values are less than those of Tables XXIV and XXV.

The results of a series of digestions run at 70° are shown in Table XXVII.

TABLE XXVII.—*Papain digestion of milk protein at 70°.*

No. of flask.	Milk.	Water.	Papain solution.	Papain.	Protein undigested.	Protein digested.	Protein digested.	Parts of protein digested by 1 part papain.
	cc.	*cc.*	*cc.*	*mg.*	*mg.*	*mg.*	*Per cent.*	
1	25	23	2	10	789	359	31.3	35.9
2	25	21	4	20	588	560	48.7	28.0
3	25	19	6	30	465	683	59.5	22.7
4	25	17	8	40	381	767	66.8	19.2
5	25	15	10	50	325	823	71.7	16.5
6	25	13	12	60	294	854	74.4	14.2
7	25	11	14	70	291	857	74.7	12.2
8	25	9	16	80	254	894	77.8	11.2
9	25	7	18	90	241	907	79.0	10.1
10	25	5	20	100	233	915	79.6	9.2

Protein in blank = 1,148 milligrams.

The digestions at 70° show that the activity in the presence of large amounts of enzyme is not greatly weakened, but with decreasing percentages of gum the loss becomes more marked. The data covering the digestions at various temperatures are plotted in fig. 4. This resistance to heat is rather unusual for an enzyme, but has been commented upon by various investigators of papain. Delezenne, Mouton, and Pozerski[8] note the rapid action upon egg white and serum at temperatures of 80° and 90°. Chittenden[9] found that papain in acid solution digests more meat protein at 70° than at lower temperatures. However, I have found that a papain solution rapidly heated to 100°, allowed to boil five seconds, and immediately cooled with ice no longer shows any proteolytic activity.

STANDARD EVALUATION OF PAPAIN

An examination of the curves in fig. 1 shows that the percentage of protein digested in thirty minutes increases rapidly with small increments of enzyme in the first portion of the curve. The range between 0.0 and 10 milligrams of papain closely approximates a straight line, especially with ordinary samples of gum, while the ratio of papain to protein digested falls off more or less rapidly beyond this point, depending upon the activity of the enzyme. The percentage of protein digested by amounts smaller than 10 milligrams of low-grade papain is so slight that this weight of gum has been decided upon as the best for routine analyses. It is suggested that the average of 6 determinations carried out in the manner previously described under "methods of analysis," using 25 cubic centimeters of milk, 23 cubic centimeters of distilled water, and 2 cubic centimeters of a filtered solution representing 10 milligrams of papain digested for thirty minutes at 40°, be accepted as the standard and that the proteolytic activity of the gum be designated by the ratio so obtained of 1 part of papain to the digested protein. This may be called the activity number of the sample.

Table XXVIII shows the activity upon this basis of the different samples of papain mentioned in this paper.

[8] *Compt. rend. Soc. biol.* (1906), 60, 68 and 309; Pozerski, *Ann. Inst. Pasteur* (1909), 23, 205 and 321.

[9] *Trans. Conn. Acad. Arts & Sci.* (1892), 9, 311.

TABLE XXVIII.—*Activity of various samples of papain.*

Sample No.	Source	Activity number.
1	Unknown	0.0
2	Ceylon	0.4
3	do	5.6
4	do	9.6
5	do	5.7
6	do	22.9
7	do	1.8
8	Mexico	12.9
9	West Indies	40.0
10	Fresh latex	45.8
11	Philippine, sundried	35.4
12	Philippine, alcohol precipitation	[illegible]

OTHER ENZYMES IN PAPAYA LATEX

Fresh papaya latex was investigated to determine whether enzymes other than papain were present. Flasks containing the following mixtures were incubated for twenty-four hours at 40°. The solutions were made neutral to phenolphthalein before incubation.

1. Active control.

Latex	g.	1.0
Water, distilled	cc.	50.0
Toluol	cc.	0.5

2. Boiled control.

Latex, boiled 1 minute	g.	1.0
Water, distilled	cc.	50.0
Toluol	cc.	0.5

3. Active extract (made in triplicate).

Latex	g.	1.0
Sucrose	g.	0.5
Water, distilled	cc.	50.0
Toluol	cc.	0.5

No invert sugar was produced in any of these experiments, thus showing the absence of invertase.

4. Active control.

Latex	g.	1.0
Water, distilled	cc.	50.0
Toluol	cc.	0.5

5. Boiled control.

Latex, boiled 1 minute	g.	1.0
Water, distilled	cc.	50.0
Toluol	cc.	0.5

6. Active extract (made in triplicate).

Latex	g.	1.0
Starch solution, 1 per cent	cc.	50.0
Toluol	cc.	0.5

No reducing sugars were found in any of these experiments, thus showing the absence of diastase in the latex. It is probable that the reported presence of this enzyme in commercial papain is to be attributed to the adulterants used in its preparation.

The fresh latex gave a faint blue with tincture of guaiacum, indicating the presence of traces of oxidase. The color darkens to a very pronounced blue upon the addition of hydrogen peroxide, while a control sample boiled for one minute gave no color. The fresh latex gave no color with *p*-phenylene diamine, but turned deep red at once upon the addition of hydrogen peroxide. Similar results were obtained with Röhmann's reagent (*p*-phenylene diamine and alpha naphthol in sodium carbonate solution).

The fresh latex, therefore, contains considerable amounts of a peroxidase, the presence of which is doubtless responsible for the darkening of color that takes place so readily during drying.

Digestion mixtures, using olive oil or ethyl acetate as the substrate, were incubated for forty-eight hours in the usual manner employed in testing for fat-splitting enzymes. The presence of lipase could not be definitely established, although in some cases a slight increase of acidity indicated the possibility of traces being present.

YIELD OF PAPAIN

It is difficult to estimate the amount of papain that may be obtained from papaya trees grown especially for this purpose. There is no doubt but that proper cultivation greatly increases the available supply of latex and that rich free soil produces plants more capable of recuperating from the effects of tapping. Under ordinary conditions such as prevail in Ceylon, a yield of 1 kilogram of fresh latex may be obtained from about 5 trees. Much depends upon the age of the plant and the maturity of the fruit at the time of tapping. Small immature fruits give a meager flow of latex that coagulates immediately, while larger papayas, about two-thirds mature, give a much larger yield and are to be chosen for tapping. The latex from such fruits does not coagulate rapidly, but freely drips into the collecting dish for several minutes following scarification. Two hundred fifty such fruits gave 1 kilogram of fresh latex, representing about 200 grams of well-dried papain. This is a much lower yield than may be obtained under favorable conditions. Forty fruits of medium size averaging about 800 grams in weight yielded 1 kilogram of latex, or 3 per cent. An average

tree in full bearing produces from 40 to 50 fruits during a season.

Subsequent tappings of the same fruits give a further amount of latex, but the yield in this case is considerably less. The fruits ripen more rapidly after scarification and are injured in appearance, but suffer little if any in flavor. They are not acceptable in the market, but could be utilized in various ways as a by-product where trees are primarily grown for the manufacture of papain.

PREPARATION OF PAPAYA

Papaya trees mature rapidly, and suffer little from the attacks of insects or plant diseases. They are generally propagated from the seed, which should be planted in boxes filled with rich earth, the seeds being about 2 centimeters apart each way and at a like depth. The plants grow freely, and may be transplanted at the end of three weeks. They should be placed about 3 to 4 meters apart, well watered, and shaded for a time. If a nursery is used, the plants may be set out from 20 to 30 centimeters apart in rows at intervals of 1 meter. The young plants should preferably be transplanted before reaching a height of over 30 centimeters. Some of the seedlings will be males, and the majority of these should be replaced by either females or bisexual plants. The trees may be depended upon to blossom and produce fruit within a year, but the number and size of the fruits will not reach a maximum until the following season. Tapping may be carried out during the second year and thereafter, until the trees become unprofitable due to age and the decreasing size of the papayas. When the trees become so tall that the latex is difficult to gather, the trunk may be cut off at a height of about 1 meter from the ground. Buds will form from the stump and produce new branches, all of which except 2 or 3 should be removed; otherwise, the fruits will be small. It has been reported that these shoots grow readily when planted, and if this is found to be the case it would probably be the best method for propagation. Seeds for planting should be saved only from the best oblong fruits that have never been tapped and have ripened on the tree.

Papaya trees are injured by water standing around the roots, and flourish best in well-drained localities. Excess water and strong winds are the principal factors causing failure, and situations should be chosen where these conditions will not be encountered. If care is taken in collecting the latex to insure freedom from foreign material and the fresh juice is dried

promptly before decomposition sets in, there should be no difficulty in preparing a white papain that would find a ready sale. Drug firms at present are at the mercy of the market, and frequently cannot obtain satisfactory papain. The enzyme should be sold under a guarantee covering its activity, thus establishing a standard which would command better prices than at present offered and avoid competition with adulterated products.

Letters from various large firms clearly show a willingness to purchase high-quality papain in relatively large quantities, single shipments ranging from 100 to 300 kilograms representing ordinary requests. It must be remembered, however, that the market is limited and, although gradually increasing, that overproduction is always a possibility. The material must be free from impurities, as nearly white as possible, thoroughly dry, and shipped in sealed containers, and must possess the requisite proteolytic activity.

The possibility of establishing a papain industry in the Philippine Islands should receive attention, as it does not necessitate a large investment of capital, and the time required is short before returns may be expected.

131717——3

ILLUSTRATIONS

PLATE I

PLATE II

TEXT FIGURES

Fig. 1. Native of Ceylon with basket made from a leaf sheath of the areca palm.

Fig. 2. Showing method of placing support and hanging basket on the tree.

PLATE I. COLLECTING PAPAYA LATEX.

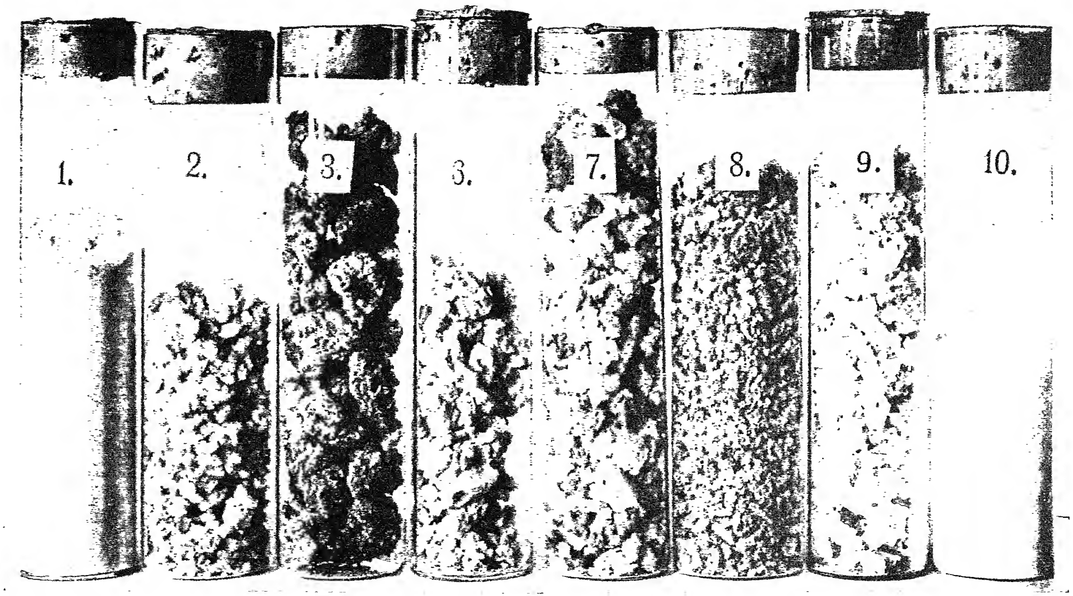


PLATE II. PAPAIN SAMPLES, ILLUSTRATING VARIOUS GRADES.

A DETERMINATION OF THE DIURNAL VARIATION OF THE RADIOACTIVITY OF THE ATMOSPHERE AT MANILA BY THE ACTIVE DEPOSIT METHOD [1]

By O. H. Blackwood

(From the Department of Physics, University of the Philippines)

FIVE TEXT FIGURES

Elster and Geitel [2] first discovered that when a negatively charged wire is exposed in the open air it becomes coated with an active deposit which may be detected by the ionization produced when the wire is placed in the ionization chamber of an electroscope. Bumstead [3] showed that the collected mass is a mixture of the active deposits of radium and thorium, and it is generally agreed that its sources are the radioactive substances in the earth. Many observers have attempted to determine the amount of emanation per cubic meter of the atmosphere by measuring the ionization produced by the active deposit collected on a given length of wire at a certain voltage and exposed for a definite period of time. Eve [4] compared the amount of active deposit collected by a wire exposed in the open air with the amount collected by a wire in a closed tank containing the decay products from a known quantity of radium bromide; and, assuming, on experimental evidence, that the wire charged to 10,000 volts collected all the active deposit from a cylindrical space 40 centimeters in radius concentric with the wire, calculated that the deposit per cubic kilometer at Montreal was in equilibrium with 0.14 to 0.49 gram of radium bromide. This is of the same order of magnitude as the amount afterwards found by Eve [5] and others by the charcoal absorption method.

The active deposit method, owing to its simplicity and to the fact that it is the only one yet devised for the detection of

[1] This work has been carried on with the encouragement of Dr. J. R. Wright, who has assisted with many valuable suggestions.

[2] *Phys. Zeitschr.* (1901), 2, 590.

[3] *Am. Journ. Sci.* (1904), IV, 18, 1–11.

[4] *Phil. Mag.* (1905), 10, 98–112.

[5] Ibid. (1907), 14, 724.

thorium-decay products in the open air, has been of great utility in the examination of the radioactivity of the atmosphere. Nevertheless, its adequacy for the absolute determination of the amount of emanation present is questionable, for the amount of active deposit collected by a charged wire undoubtedly depends upon other factors in addition to the amount of emanation present. Rutherford [6] states:

It has generally been supposed that only the positively charged atoms of radium A are collected on the wire, and that they travel in an electric field at the same rate as the positive ions. Account has to be taken of the rate of re-combination of the charged atoms of radium A with the negative ions of the air, for only those atoms reach the wire which retain their charge. The constant of re-combination is no doubt affected by atmospheric conditions, and the number of nuclei present.

At high elevations the air, owing to its reduced density, should cause a smaller resistance to the motion of the charged particles, so they should be swept in more rapidly and from a greater distance than at a lower level. Therefore, the amount of active deposit collected should increase with altitude even if the emanation remained constant. Saake [7] found that the active deposit at Arosa, elevation 1,800 meters, was three times as great as that of Wolfenbüttel. Other observers have obtained similar results. That this is not due to an increase in the emanation content is indicated by the determinations of Wright and Smith,[8] who made an investigation of the variation of the radium emanation with altitude by the charcoal absorption method and found that the emanation content at Manila, sea level, was approximately four times that obtained on Mount Pauai, elevation 2,460 meters.

Many observers have found that, for a given locality, the amount of deposit collected depends upon the direction of the wind, but there has been considerable disagreement as to the effect of the variation of the wind velocity. Kinoshita, S. Nishikawa, and S. Ono [9] deduced the lines of flow of the charged particles for different wind velocities from theoretical considerations, and found that, above a critical velocity, the variation should not affect the amount collected.

The diurnal variation of the active deposit has been the subject

[6] Radioactive substances and their radiations. Cambridge University Press (1913).

[7] *Phys. Zeitschr.* (1903), 4, 426.

[8] *This Journal, Sec. A* (1914), 9, 51.

[9] *Phil. Mag.* (1911), 22, 821.

of a very limited amount of investigation. It was first detected by Simpson,[10] who made three determinations per day in Lapland for several months and found that there was a maximum in the morning and a minimum in the afternoon. Hess [11] also found a small variation with a minimum in the evening. Neither of these observers made observations covering the entire twenty-four hours. Dike [12] secured the active deposit by forcing a measured stream of air past charged screens. His mean curve for six series of observations, each set of observation extending over a period of about twenty hours, shows a striking variation. The maximum comes soon after midnight, *and is more than twenty times the minimum.*

In the present investigation the meteorological data were secured from the Manila Observatory, which is about 0.1 kilometer from the point where the measurements were made. The method was similar to that commonly used in active deposit observations. The testing apparatus was a standard Exner electroscope. The hollow, brass supporting neck was filled with sulphur which supported a central rod and a guard ring, the latter was kept charged to 240 volts by means of a storage battery in order to reduce the natural leak. The upper end of the central rod supported the gold leaf, while the end entering the ionizing chamber was rigidly attached to a wire cage 9 centimeters in diameter and 17 centimeters high. The ionizing chamber was of sheet brass, 22 centimeters in diameter and 24 centimeters deep. A saturation test of the apparatus showed that for the voltage used in the determinations more than 85 per cent of the negative ions reached the charged system. The capacity of the system was about 18 electrostatic units. The motion of the leaf was observed by means of a telescope having a micrometer eyepiece. The electroscope had a sensitiveness of approximately 5 divisions per volt. A bare wire was wound on an iron reel fitting snugly into the ionizing chamber. After the introduction of the reel, the bottom of the chamber was closed, the leaf charged to 240 volts, and the motion of the leaf in divisions per minute recorded as the natural leak. The wire was then stretched horizontally, by means of ebonite rods, at a mean elevation of 3 meters, in the open space north of the physics building. Since no static machine was at first avail-

[10] *Phil. Trans. Roy. Soc. London* (1905), A, 205, 61.
[11] *Sitzungsber. Akad. d. Wiss., math.-nat. Klasse,* Wien (1910), 119, 145.
[12] *Terr. Mag.* 1906), 7, 125.

able, the wire was charged by a metal comb which was brought near to another comb fastened to the negative terminal of a Thordarsen induction coil capable of giving a 20-centimeter spark. The silent leak across the air gap was usually sufficient to keep the deflection of a Braun electrostatic voltmeter constant at about 3,000 volts. After midnight, however, the humidity was so great that the potential could not be maintained, so a motor-driven static machine was substituted for the induction coil, the aërial being connected directly to the negative terminal. With this the potential was kept at 8,000 volts, the pressure being regulated by varying the distance between two combs, one of which was in contact with the wire, while the other was grounded. After the wire had been exposed for thirty minutes, it was wound on the reel and introduced into the ionizing chamber. After ten minutes the leaf was charged to 240 volts by means of storage cells, and the time for it to move 40 divisions was recorded as the reciprocal of the amount of active deposit on the wire.

Amount of active deposit at Manila.—Elster and Geitel [18] took as a measure of the amount of active deposit present the leak per hour in volts which would be caused by the active deposit collected by a wire 1 meter long which had been exposed for two hours at a negative voltage of 2,500, the testing system having a capacity of 9.5. The capacity of my electroscope was about 18 electrostatic units, otherwise the experiments were carried on in the same manner. A wire 30 meters long exposed at Manila gave a mean discharge for 5 observations of 300 volts per minute. If the capacity of my electroscope had been 9.5, as in the case of the Elster and Geitel experiment, the discharge would have been about 568 volts per minute. Therefore, a wire 1 meter long would give a discharge of about 19. This is approximately the same as the mean value found by Elster and Geitel for Wolfenbüttel.

Diurnal variation of the active deposit.—The diurnal variation was determined as follows: The wire was exposed at 8,000 volts for a period of thirty minutes. It was then tested as described above, and the time for the leaf to move 40 divisions was recorded as the reciprocal measure of the amount of active deposit collected. The actual determinations are given in Table I.

[18] *Phys. Zeitschr.* (1903), 4, 526.

TABLE I.—*Diurnal variation of active deposit.*

[Length of wire, 30 meters; voltage, 8,000; time of exposure, 30 minutes.]

Date	Time after midnight.	Reciprocal of time for leaf to move 40 divisions.	Relative humidity.	Wind. Direction.	Wind. Force in kilometers per hour.
1914.	*Hrs.*				
Jan. 26	10	0.028			
Jan. 27	19	0.008			
Jan. 28	21	0.018			
Do	24	0.050			
Jan. 29	3	0.143			
Do	5	0.121			
Do	6½	0.033			
Do	9	0.033			
Do	11½	0.022			
Do	15	0.016			
Do	17	0.018			
Do	20½	0.019			
Feb. 2	20½	0.018	76	ESE	8½
Feb. 3	¼	0.014	83	Calm	2
Do	2	0.012	86	Calm	0
Do	3	0.033	86	Calm	1
Do	4	0.121	88	Calm	1
Do	5	0.091	86	Calm	½
Do	6½	0.025	92	Calm	3
Do	9½	0.020	79	SSW	3½
Do	11½	0.033	72	SW	9
Do	13	0.050	68	SE	8
Do	19	0.007		Calm	
Feb. 4	20	0.033	82	Calm	2
Feb. 5	1	0.033	89	Calm	3
Do	2	0.050	88	E	6
Do	3	0.062	91	NE	4
Do	3½	0.100	91	NE	4
Do	5	0.050	93	Calm	3
Do	6	0.036	93	Calm	2½
Do	9	0.030	68	ESE	16
Do	12	0.033	55	EbyS	22
Do	16	0.026	48	ESE	20
Do	18½	0.009	58	ESE	16
Do	20½	0.013			
Feb. 9	21	0.013	74	ESE	8
Do	24	0.030	84	Calm	1½
Feb. 10	3	0.125	77	Calm	1½
Do	7½	0.025	80	Calm	0
Do	8½	0.017	62	NE	12½
Do	11½	0.017	58	NE	9½
Do	14½	0.014	69	Calm	5½
Do	16½	0.015	63	NNE	14
Feb. 16	8	0.008	66	Calm	3
Do	9	0.025	55	EbyS	4½
Do	12	0.017	55	W	17
Do	14	0.011	46	W	10

TABLE I.—*Diurnal variation of active deposit*—Continued.

Date.	Time after midnight.	Reciprocal of time for leaf to move 40 divisions.	Relative humidity.	Wind	
				Direction.	Force in kilometers per hour.
1914.	*Hrs.*				
Feb. 16	16	0.008	47	SE	22
Do	20½	0.020	58	ESE	10
Do	24	0.045	79	ESE	8
Feb. 17	3½	0.076	87	NNE	4½
Do	7	0.033	89	NE	1½
Mar. 9	16	0.009	44	SE	27
Do	17	0.009	57	SE	18
Do	21	0.011	78	SE	7
Do	23½	0.060	84	ESE	6
Mar. 10	½	0.040	87	Calm	[illegible]
Do	3	0.033	94	E	[illegible]
Do	5	0.033	93	ENE	[illegible]
Do	6	0.018	91	Calm	[illegible]
Do	9½	0.020	61	Calm	[illegible]
Do	13	0.075			
Mar. 18	13½	0.010	58	SSE	[illegible]
Do	17	0.008	57	SE	[illegible]
Do	20	0.009	67	SE	[illegible]
Do	22½	0.025	73	E	[illegible]
Do	24	0.020	83	Calm	3
Mar. 19	1½	0.025	79	E	6
Do	2	0.033	83	Calm	1
Do	3	0.014	80	Calm	2
Do	4	0.025	83	Calm	1
Do	5	0.026	86	Calm	½
Do	6½	0.028	89	Calm	1½
Do	9	0.024	66	W	9
Do	11½	0.014	66	WNW	15
Do	12½	0.010	59	WNW	11½
Mar. 24	20½	0.006	67	SE	8
Do	24	0.017	73	NE	11
Mar. 25	3	0.050	80	Calm	2½
Do	4	0.052	84	Calm	0
Do	8½	0.022	65	ENE	3
Do	10½	0.017	67	W	5
Do	11½	0.020	59	W	14
Do	15½	0.005	37	SE	23
Do	17	0.012	36	ESE	18
Mar. 30	10	0.022	61	SSW	4
Do	13½	0.012	56	W	15
Do	16½	0.010	45	SE	7
Do	22½	0.010	76	SSE	9
Mar. 31	2	0.025	83	Calm	0
Do	5	0.050	83	Calm	0
Do	7	0.012	77	Calm	0
Do	8½	0.015	69	Calm	1
May 4	21½	0.020	62	ESE	7
Do	22½	0.030	70	SE	8

TABLE I.—*Diurnal variation of active deposit*—Continued.

Date	Time after midnight.	Reciprocal of time for leaf to move 40 divisions.	Relative humidity.	Wind. Direction.	Wind. Force in kilometers per hour.
1911.	*Hrs.*				
May 4	23½	0.033	73	SE	6
May 5	½	0.029	79	Calm	2
Do	1½	0.040	81	Calm	3
Do	2½	0.040	80	Calm	3
Do	3½	0.050	80	Calm	3
Do	4½	0.055	83	Calm	1
Do	6	0.033	80	Calm	2
Do	10½	0.025	70	WNW	10
Do	11½	0.015	72	WNW	16
Do	15	0.012	48	SE	17
Do	19½	0.008	68	ESE	7

The wind, humidity, and active deposit were plotted as ordinates with the times after midnight as the abscissæ. The collection on windy days did not differ noticeably from those taken in times of calm, and variations of the wind were not accompanied by corresponding fluctuations in the deposit (fig. 5); so, apparently, variation of the wind velocity does not affect the amount of active deposit collected. All the active deposit curves show minima in the evening and maxima after midnight. The depression shown in Dike's curve for early morning is lacking in all of my observations. From the mean curves (figs. 2, 3, 4) it will be seen that there are corresponding variations in the humidity and deposit, but the individual curves show that minor variations of the humidity are not usually accompanied by variations of the deposit, which indicates the existence of other factors (fig. 5). One of these factors is the variation in the emanation content, since Wright and Smith[14] have found that the night emanation content at Manila, as measured by the charcoal absorption method, is about twice that of the day.

DIURNAL VARIATION AT A HIGH ELEVATION

Observations of the active deposit were made on Mount Maquiling, 60 kilometers from Manila, at an elevation of about 1,140 meters. The apparatus was similar to that used at Manila except that the guard ring was eliminated. The electroscope

[14] *This Journal, Sec. A* (1914), 9, 68.

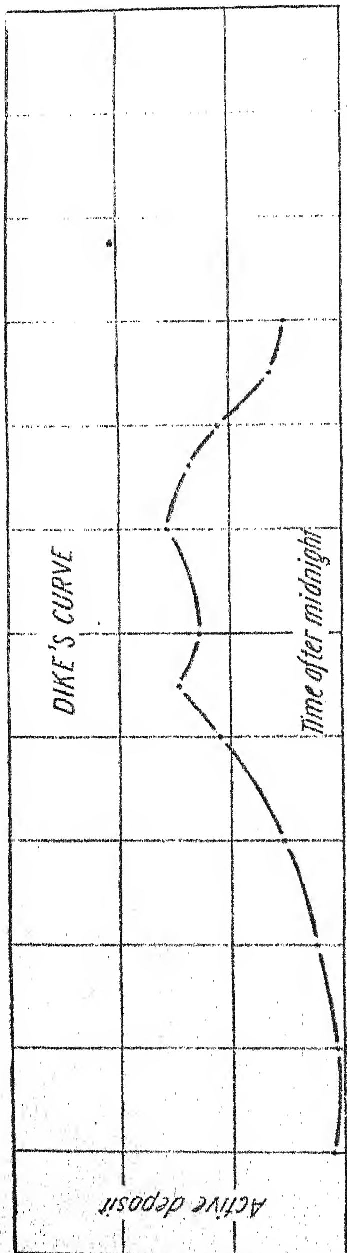


Fig. 1. Active deposit curve.

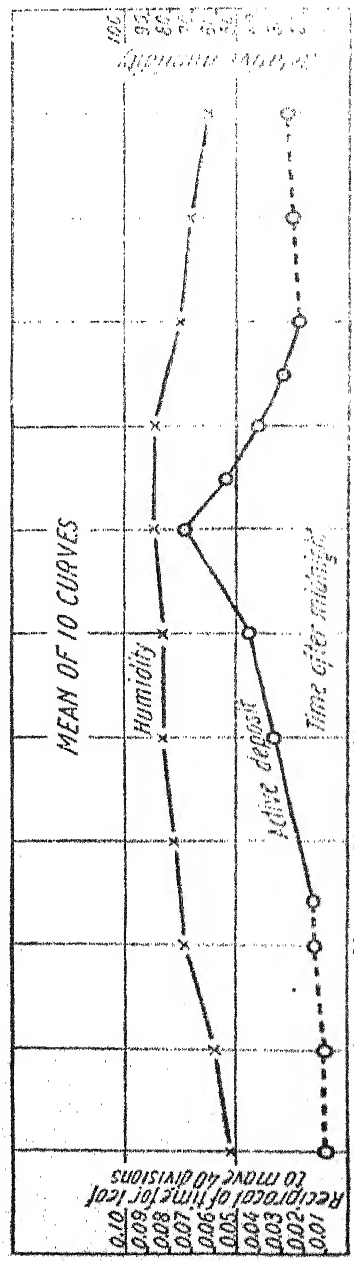


Fig. 2. Active deposit and humidity curve.

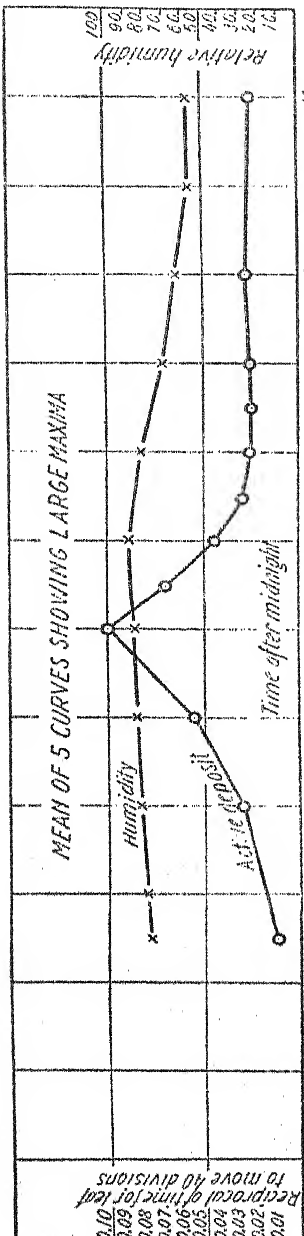


FIG. 3. Active deposit and humidity curves.

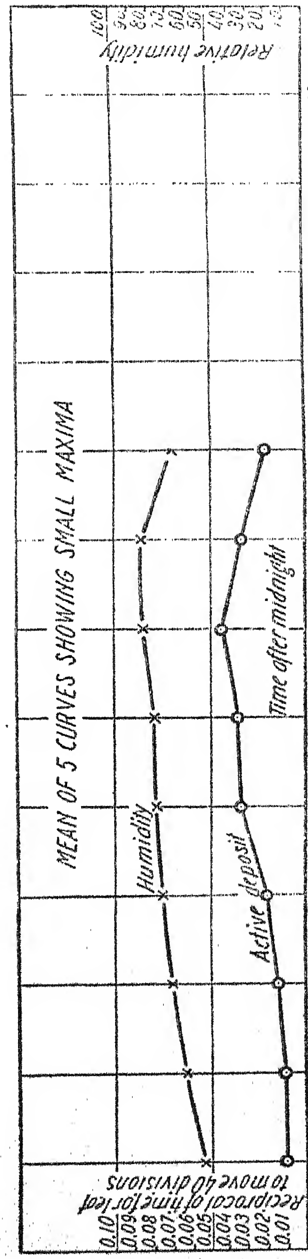


FIG. 4. Active deposit and humidity curves.

was charged by means of an ebonite rod. The humidity, as shown by a self-registering hygrometer, remained above 90 per cent even at midday, and at night it was found necessary to heat the ebonite rods in order to maintain the voltage. The number of determinations is hardly sufficient to justify definite conclusions, but the night determinations are all smaller than the mean-day collection, and apparently the diurnal variation is the inverse of that at Manila. Five daytime determinations made at Manila with the apparatus as used on the mountain gave a

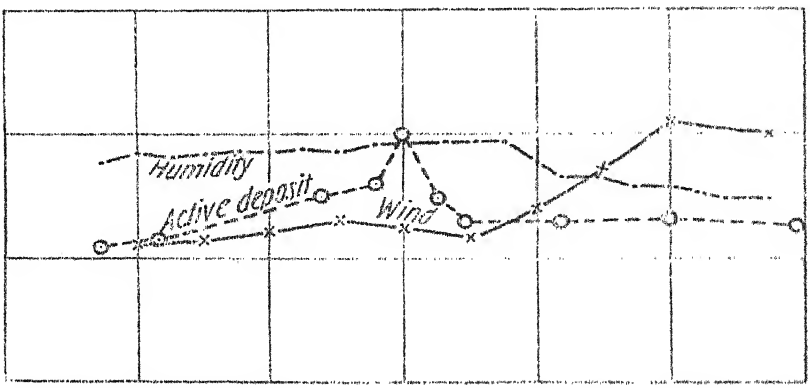


FIG. 5. Humidity, active deposit, and wind curves for February 4, 1914.

mean value for the active deposit approximately one-half that of Mount Maquiling.

Ratio of the amount of radium active deposit to thorium active deposit at Manila.—A wire was exposed as outlined above, and the voltage was kept at 10,000 for ninety minutes. The discharge was measured every three minutes after the introduction of the cage into the ionizing chamber and the ionization curve plotted. Thirteen closely agreeing determinations were made, and the mean time required for the rate of discharge to fall to one-half was found to be sixty-two minutes. According to the determination of Harvey,[15] this corresponds to less than 15 per cent thorium active deposit.

[15] *Phys. Rev.* (1912), 35, 9123.

TABLE II.—*Diurnal variation of the active deposit collected on Mount Maquiling, Laguna Province, Luzon.*

Date.	Time after midnight.	Reciprocal of time for leaf to move 40 divisions.
1914.	*Hrs.*	
May 16	8½	0.017
Do	10	0.017
Do	12	0.014
Do	14	0.008
Do	17½	0.010
Do	22	0.008
May 17	3	0.008
Do	7	0.012
Do	9½	0.029
Do	13½	0.017
Do	16½	0.040
Do	19	0.021
May 18	½	0.005
Do	6½	0.005
Do	9	0.008
Do	12	0.012
Do	14½	0.022
Do	18	0.014
Do	21	0.004
May 19	7½	0.008
Mean day value		0.007
Mean night value		0.09

SUMMARY

1. The mean day-value of the active deposit at Manila is about the same as that of Wolfenbüttel.

2. (a) There is a large and fairly regular diurnal variation of the active deposit at Manila, the mean night-value being about three times that of the day. (b) The mean active deposit seems to vary with the humidity, but in the individual curves there are wide divergences. (c) There is no evident relation between the wind and the amount of deposit collected.

3. (a) The active deposit collected on Mount Maquiling, elevation 1,140 meters, is about twice that of Manila. (b) The diurnal variation on the mountain is apparently the inverse of that of Manila, the night collection being smaller than the day.

4. The half-period value found at Manila is about sixty-two minutes, which corresponds to less than 15 per cent thorium active deposit.

ILLUSTRATIONS

TEXT FIGURES

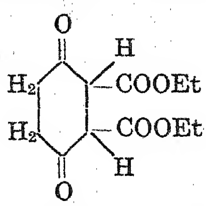
DIETHYLSUCCINOSUCCINATE (ETHYLDIOXYDIHYDROTERAPHTHALATE): A STUDY OF ITS CONSTITUTION, SOME DERIVATIVES, AND ABSORPTION SPECTRA [1]

By H. D. Gibbs and H. C. Brill

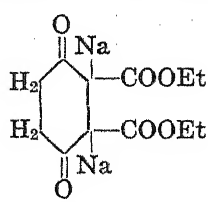
(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

THREE TEXT FIGURES

Fehling [2] first produced dimethylsuccinosuccinate in the course of his studies on the action of alkali metals upon methysuccinate. The work of F. Herrmann [3] added greatly to the knowledge of the structure of this compound. He gives formulas to show its relation to phthalic acid in the sense of the formula



and for the sodium salt he gives the formula



in both of which the carboxyl groups are in the ortho position.

Düisberg [4] pointed out the fact that neither the above formula nor the formula in which the carboxyl groups are in the para position was proven.

The work of Geuther,[5] Wedel,[6] and Ebert [7] also contributed

[1] Received for publication August 18, 1914.

[2] *Ann. d. chem.* (1844), 49, 192.

[3] *Ann. d. chem.* (Liebig) (1882), 211, 306.

[4] *Ber. d. deutschen chem. Ges.* (1883), 16, 138

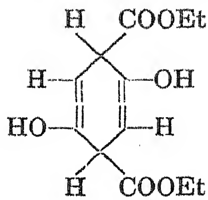
[5] *Ann. d. chem.* (1883), 219, 119.

[6] Ibid. (1883), 219, 71.

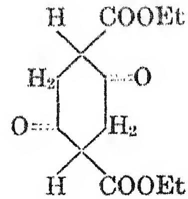
[7] Ibid. (1885), 229, 45.

to the knowledge of the structure of the compound. The latter discussed the probability of the carboxyl group being in the para position.

Baeyer [8] showed the relationship to terephthalic acid and that the compound must exist in the two forms

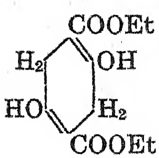


Enol.

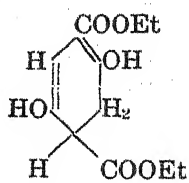


Keto.

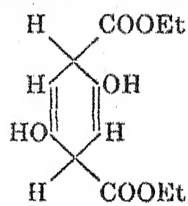
The latter conclusion was based upon the fact that phenylhydrazine, ammonia, and hydroxylamine react as if the compound were in the keto form, while the reaction with acetyl chloride (forming a diacetate) and the salt formation with alkalies indicated the enol form. He also shows that the three representations



$\Delta^{1,4}$

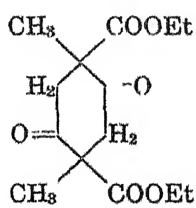


$\Delta^{1,5}$



$\Delta^{2,5}$

are possible for the enol form.[9] He later prepared the derivative



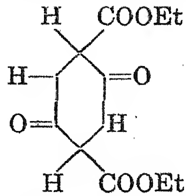
by treating the sodium compound of ethylsuccinosuccinate with methyl iodide. This compound yields a mono- and a diphenylhydrazone, as would be expected from the above representation, in the same manner as does ethylsuccinosuccinate itself.

[8] *Ber. d. deutschen chem. Ges.* (1886), 19, 428 and 1799. See also Baeyer and Tutein, Ibid. (1889), 22, 2189.

[9] *Ann. d. chem.* (1888), 245, 190.

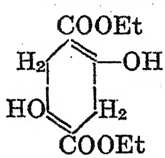
The existence of mixed crystal forms in ethylsuccinosuccinate and diethylquinonedihydroparacarboxylate was discovered by Lehmann and discussed by Herrmann.[10] The possibility of the existence of desmotropic forms and derivatives has been discussed by Hantzsch and Herrmann.[11]

Hantzsch [12] refers to the oxidation of ethylsuccinosuccinate as producing quinonedihydroterephthalic ester of the constitution



which may indicate that the 3, 6 hydrogen atoms of ethylsuccinosuccinate are the first to be oxidized.

From the work described in this paper we believe that ethylsuccinosuccinate can exist in two forms, the enol and keto, cis and trans modifications being also possible; it seems reasonable to assume that one of these in the keto compound will favor the migration to the enol form. Of the three forms which Baeyer shows are possible for the enol modification the $\triangle^{1,4}$



is the only one tenable when the labile hydrogen atoms are in the 1, 4 positions, which from the evidence at hand, seems to be the case.

ENOL AND KETO FORMS

When the mother liquor from which a considerable quantity of ethylsuccinosuccinate has been obtained is concentrated, a small amount of a yellow crystalline precipitate is thrown out. The purification of this compound was effected by crystallizing many times from absolute alcohol. The specimen thus obtained differs from the first precipitate formed in color, melting point, solubility, and absorption spectra and shows some differences in chemical behavior.

[10] *Ber. d. deutschen chem. Ges.* (1886), 19, 2235.
[11] Ibid. (1887), 20, 2801.
[12] Ibid. (1886), 19, 26.

The first compound thrown out is very slightly colored greenish yellow, melts at 127°, is less soluble in alcohol, the absorption band in less persistent, and the compound absorbs bromine in alcoholic solution and gives an initial pink color with sodium ethoxide. The second precipitate formed is yellow, melts at 123°, is slightly more soluble, its absorption band is the more persistent, does not absorb bromine, and gives an initial red color with sodium ethoxide.

The two specimens were treated in cold alcoholic solution with alcoholic bromine solution by the method of Kurt H. Meyer [13] to determine the percentage of enol and keto forms. The light-colored samples were shown by the average of a number of titrations to be approximately 90 per cent enol, while the yellow specimen reacted only to a very slight extent with the bromine solution (1 or 2 drops producing a bromine color), showing it to be practically all in the keto form. (The calculation is based upon the addition of 4 atoms of bromine to 1 atom of the ester.)

This behavior of the compound was noted by F. Herrmann,[14] while preparing a bromine addition product of ethylsuccinosuccinate. His preparations would not absorb the theoretical amount of bromine and he states that the yellow color obtained at the end of the titration was not necessarily due to free bromine but to decomposition products. In the light of our present knowledge we believe the yellow color of the solution, after complete bromine absorption, to be due to the keto form which has been unacted upon.

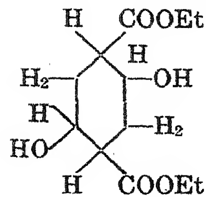
REDUCTION OF ETHYLSUCCINOSUCCINATE

On treating an alcoholic solution of ethylsuccinosuccinate (90 per cent enol form) with a small quantity of concentrated hydrochloric acid and adding zinc dust in small amounts a colorless crystalline substance is thrown out of the solution. This compound is practically insoluble in alcohol and water, but is soluble in warm toluene from which it can be thrown out in beautiful colorless crystals by the addition of alcohol; melting point, 120°. It is soluble in alkalies, forming a solution which quickly turns brown in the air. On treatment with acetyl chloride a derivative is formed which melts at 167°, 2 degrees below the melting point of the diacetyl derivative of ethylsuccinosuccinate. It becomes yellow on heating, while the diacetyl derivative of

[13] Ann. d. chem. (1911), 380, 212.

[14] Ber. d. deutschen chem. Ges. (1886), 19, 2229.

ethylsuccinosuccinate does not. Mixtures of the two compounds melt at 166°. It is possible that this is the reduced ethylsuccinosuccinate of the following constitution:



The absorption spectrum shows some differences from the known diacetyl derivative. It was observed that the crystals of diethylsuccinosuccinate which form on cooling the filtrate obtained after the reduction with zinc dust and hydrochloric acid are more yellow than the original compound employed. This may indicate that the enol form is more readily reduced, the keto form remaining in a greater proportion than was originally present.

Absorption spectra.—The absorption spectra of two samples of ethylsuccinosuccinate, one 90 per cent enol melting at 127° and the other practically all keto melting at 123°, in neutral alcohol solution and with 2 equivalents of sodium ethoxide, and the diacetate of ethylsuccinosuccinate are plotted in fig. 1.

It is to be noted that the absorption band heading at $1/\lambda=2{,}660$ in neutral solution is more persistant in the keto form, while in alkaline solution the reverse is the case. This points to the conclusion that the color is due to the keto form and that this compound is less affected by alkalies. The curve of the acetyl derivative shows no absorption band and leads to the conclusion that the labile hydrogen of the hydroxyl is necessary to selective absorption. The shift of the band produced by sodium ethoxide is found in all hydroxy benzene derivations examined.[15]

The absorption curve of the diimide [16] of ethylsuccinosuccinate in neutral solution and in the presence of an excess of hydrochloric acid are plotted in fig. 2.

Since this compound is a derivative of the keto form in which the oxygen atoms are replaced by the more active =NH groups, it is to be expected that it will be more highly colored than the keto ethylsuccinosuccinate and show a greater absorption band in the same region of the spectrum. Acids form salts with this

[15] Gibbs and Pratt, *This Journal, Sec A* (1913), 8, 33.
[16] Baeyer, *Ber. d. deutschen chem. Ges.* (1886), 19, 429

compound and saturate the free affinities of the nitrogen atom destroying the band.

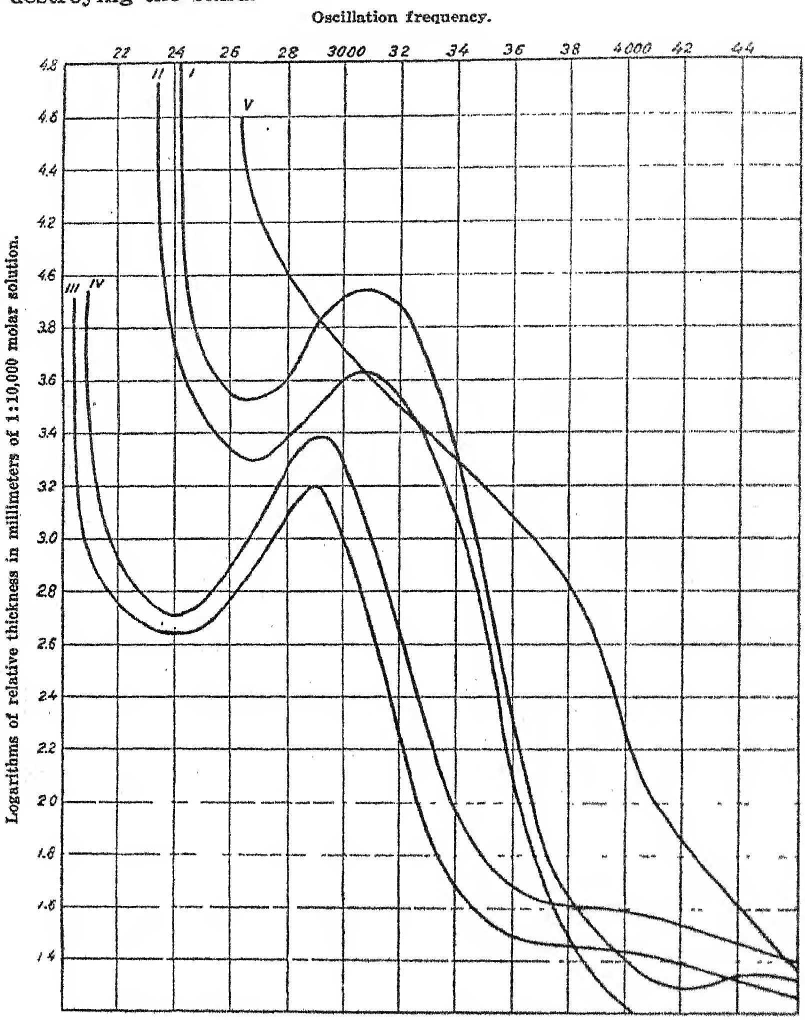


FIG. 1. *Curve I.* Diethylsuccinosuccinate in alcohol. Light yellow modification. *Curve II.* Diethylsuccinosuccinate in alcohol. Deep yellow modification. *Curve III.* Diethylsuccinosuccinate in alcohol plus 2 equivalents of sodium ethylate. Light yellow modification. *Curve IV.* Diethylsuccinosuccinate in alcohol plus 2 equivalents of sodium ethylate. Deep yellow modification. *Curve V.* Diacetyldiethylsuccinosuccinate in alcohol.

The absorption curves of methylsalicylate in neutral alcohol and in the presence of a great excess of sodium ethoxide and of the acetyl derivative of methylsalicylate are plotted in fig. 3.

The great difference in the curve of the acetyl derivative from those of the first two compounds, shows that the fixation of the labile hydrogen atom has the same general effect as in ethylsuccinosuccinate and its diacetyl derivative. In the latter the spectrum shows only general absorption since the benzene ring

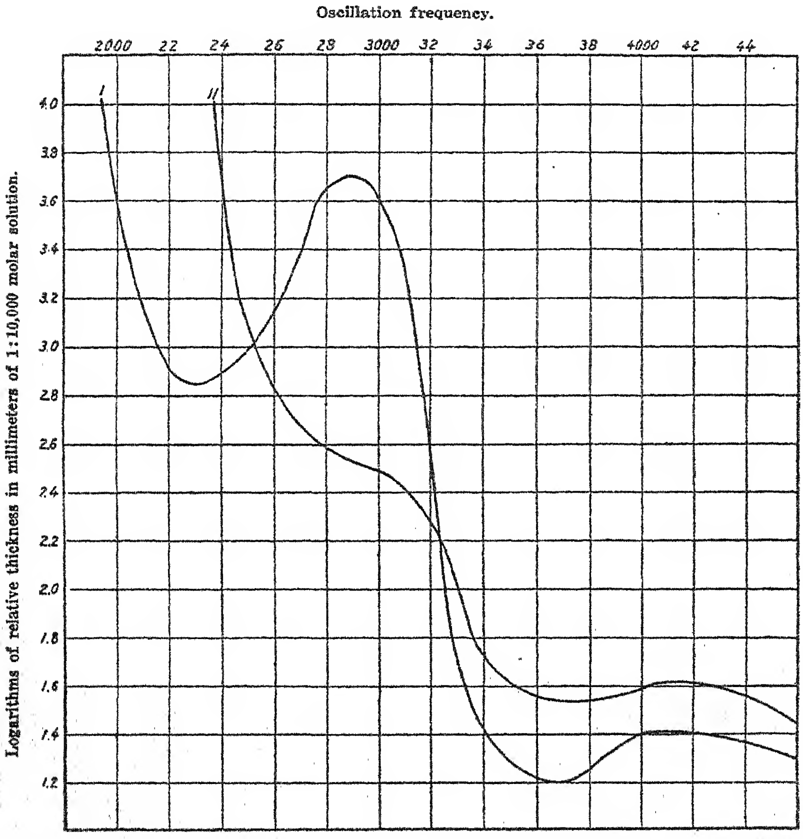


FIG 2. *Curve I. P*-diimide of diethylsuccinosuccinate in alcohol. *Curve II. P*-diimide of diethylsuccinosuccinate in alcohol plus 2 equivalents of hydrochloric acid.

is more nearly saturated. The entire disappearance of an absorption band in acetylmethylsalicylate is not to be expected since phthalic acid [17] and phthalic anhydride show a similar absorption band due to the effect of the vibration of the benzene ring.

[17] Pratt, *This Journal, Sec. A* (1913), 8, 399.

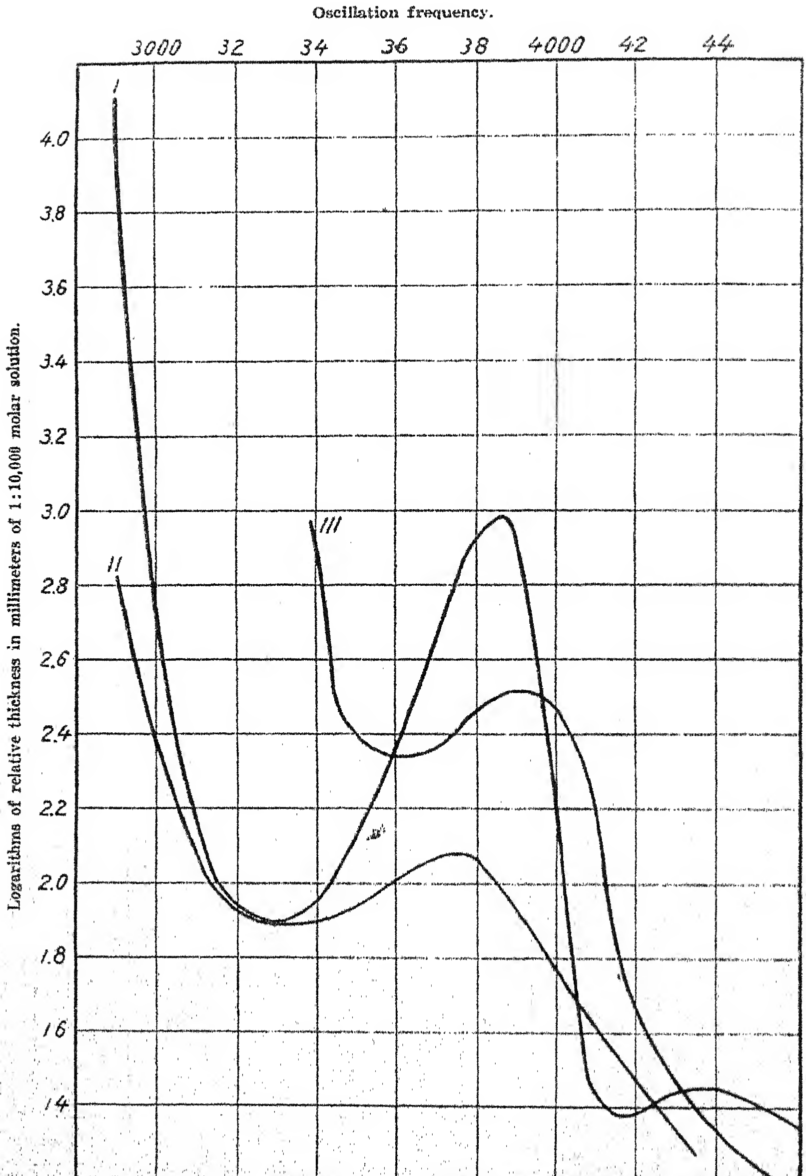
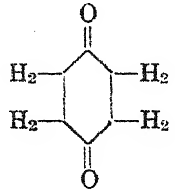


FIG. 3. *Curve I.* Methylsalicylate in alcohol. *Curve II.* Methylsalicylate in alcohol plus 500 equivalents of sodium ethylate. *Curve III.* Acetylmethylsalicylate in alcohol.

The color of the yellow form of ethylsuccinosuccinate is due not to an absorption band in the visible region of the spectrum, but to a band which lies so close to the visible region, heading at $1/\lambda=2{,}660$, that at the higher concentrations it broadens into the visible. Since the persistence and breadth of this band probably depend upon the relative amounts of enol and keto forms present and since the diacetyl derivative gives no band at all, it is quite possible that the pure enol form will be colorless and that the absorption band heading at $1/\lambda=2{,}660$ may be absent. The equilibrium existing between the two forms in alcohol solution has so far precluded the photographing of the pure enol form without first fixing the labile hydrogen atoms. The band of the keto from is not due solely to the =CO groups in the para position but to the influence exerted upon them by the neighboring carboxyl groups. Tetrahydroquinone and its dioxime are colorless;



it seems probable, however, that these compounds will show absorption bands near the visible region of the spectrum, due in the case of the former to the mutual influence of the carbonyl groups, in a manner similar to that found in diacetyl. The neighboring carboxyl groups in ethylsuccinosuccinate may merely shift this band slightly so that it falls nearer the visible region.

Baeyer and Noyes [18] found that tetrahydroquinone reacts with acetyl chloride and forms a white precipitate in ether solution on the addition of sodium alcoholate and that it, therefore, may exist in two forms, the enol and keto.

Diethylsuccinosuccinate in addition to the enol and keto, may have stereoisomeric modifications, the cis and the trans forms. Since stereoisomerism is only possible when the carbon atoms to which the carboxyl groups are attached are saturated, wandering hydrogen atoms in the 1, 4 positions in the keto form preclude the existence of cis and trans modifications. It seems reasonable to assume that in the keto form this change takes

[18] *Ber. d. deutschen chem. Ges.* (1889), 22, 2168.

place more readily when the 1, 4 hydrogen atoms are in a position to most influence the =CO groups.

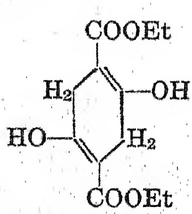
The absorption band of ethylsuccinosuccinate heading at $1/\lambda=2{,}660$ is shifted to $1/\lambda=2{,}400$ in the presence of sodium ethoxide. This shift in position is entirely analogous to the shift in the band of methylsalicylate and argues for a similar structure.[19] It has been shown that in methylsalicylate [20] and some related compounds the influence of the carboxyl upon the hydroxyl group is very marked and that the =CO group of the carboxyl is so affected by the neighboring hydroxyl that, in certain respects, the ester behaves more like an ether.

Acetylmethylsalicylate.—This compound was produced in a manner analogous to that employed by Freer [21] for the production of the ethyl derivative; namely, by boiling methylsalicylate with an excess of acetyl chloride. The yield seemed to be increased by the presence of a small quantity of pyridine. The ethyl ester boils at 272°, while we have found that the methyl derivative boils at about 265° with decomposition. Final purification was effected by distilling. A distillate with a constant boiling point at 7 millimeters pressure of 122° was obtained. This product was colorless, odorless, and produced only the faintest coloration with ferric chloride solution.

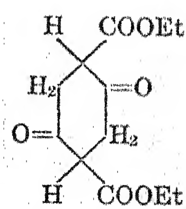
SUMMARY

The absorption spectra of ethylsuccinosuccinate in neutral and alkaline alcohol solutions, the diacetate in neutral solution, the diimide in neutral and acid solutions, and acetylmethylsalicylate, have been measured.

As a result of this work we believe that ethylsuccinosuccinate exists in two forms, the enol and keto, which have different melting points:



$\Delta^{1,4}$ enol.



Keto.

[19] Gibbs and Pratt, *This Journal, Sec. A* (1913), 8, 44.

[20] Gibbs, Williams, and Galajikian, *This Journal, Sec. A* (1913), 8, 1; and Gibbs and Pratt, loc. cit.

[21] *Journ. f. pr. Chemie* (1893), 47, 246.

that the pure enol form is colorless, while the keto form is yellow due to general absorption or the extension of an absorption band lying near the visible region. The fixation of the labile hydrogen atom or the saturation of the free affinities of the oxygen atoms in the para position destroys the absorption band. The behavior of this compound in the enol form is quite similar to that of methylsalicylate.

ILLUSTRATIONS

TEXT FIGURES

WATER SUPPLY FOR THE CITY OF ILOILO [1]

By GEORGE W. HEISE

(From the Laboratory of General, Inorganic, and Physical Chemisry, Bureau of Science, Manila, P. I.)

ONE TEXT FIGURE

Iloilo, one of the largest and most important cities in the Philippine Islands, is greatly in need of a municipal water supply system, yet the problem of obtaining good water in adequate quantities is rather complex. Most of the surface waters in the vicinity are high in mineral content, and are of objectionable taste, and the artesian waters are almost all brackish, high in iron, and extremely hard. There is no suitable water available for boiler use and no supply for fire-fighting purposes. A number of the residents have accustomed themselves to drinking the water from the artesian wells, without experiencing any noticeable ill effects; many construct large rain-water cisterns; many have their drinking water carried from comparatively great distances, either from surface wells in outlying districts or from springs on Guimaras Island, across the straits from the city; many obtain distilled water from the local ice plant. As might be inferred, the situation is highly unsatisfactory. The artesian waters are so hard and brackish that they are unsatisfactory both for household and boiler use; the cistern supply, questionable at best owing to its susceptibility to contamination, is liable to fail during a long dry season; the waters carried for long distances are subject to pollution, both at the source and during transit; the distilled water is expensive and is available only for drinking purposes.

For some years the Bureau of Public Works has been developing projects for supplying the city with water. Iloilo and its environs, including Molo, La Paz, and Mandurriao, have a population of approximately 55,000 to be provided for, hence they would require, at a rough estimate based on the water consumption of Manila, a supply of about 11,350,000 liters (3,000,000 gallons) per day. Thus far three main projects have been proposed: (1) To dig enough artesian wells in the outlying districts to develop a town supply; (2) to throw a dam across Tigon River at Maasin, impounding an adequate amount of water which could be piped to the city; (3) to get water from the springs and upland water courses of Guimaras Island and to bring it to Iloilo by pipes laid beneath the straits separating the island from the mainland.

[1] Received for publication January 29, 1915.

I was detailed to make a "sanitary survey" of the available water supplies of Iloilo with a view toward determining the relative merits of the different projects. Accordingly a field

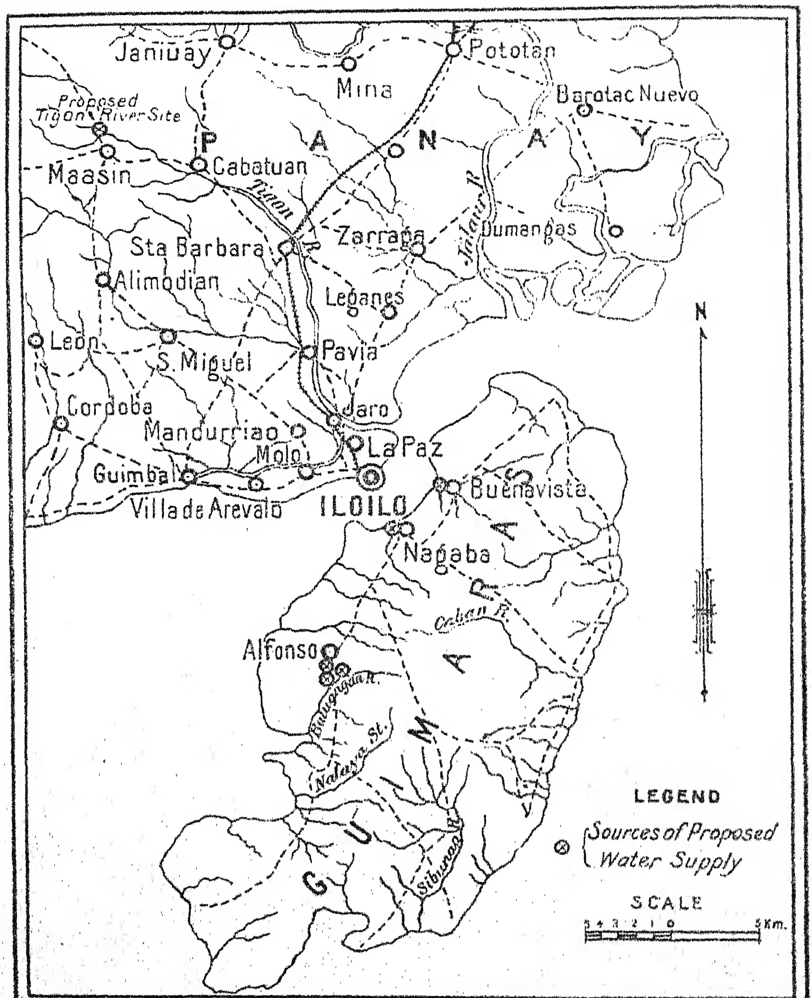


FIG. 1. Guimaras Island and a part of Panay.

investigation including chemical assays and biological examinations was undertaken in November, 1914, the results of which are detailed herewith.

The methods of chemical examination employed in this work were, with some modifications, those outlined by Leighton.[2] The errors and limits of accuracy involved have been discussed by the same author. In addition bacteria counts on litmus lactose agar and tests for gas-forming organisms in lactose bile agar were made with the aid of a small portable bacteriological outfit.

DEEP WELLS

Many wells have been drilled in the vicinity of Iloilo by the Bureau of Public Works. Most of them are from 60 to 80 meters deep, and no potable waters have been found at greater depths, although borings have been extended to over 700 meters.

The artesian well project involved drilling a battery of wells at Molo, a few kilometers from Iloilo, large enough to furnish sufficient water to supply the city. In some way it had come to be generally believed that the artesian wells already completed in that vicinity were gradually losing their salt content, and that the improvement of the water was sufficient to justify its development for a municipal supply. Just how this idea originated is not quite clear; perhaps it was due to the fact that people quickly accustom themselves to surprisingly large amounts of salt in drinking water and that their ability to detect salt by its taste is correspondingly decreased. That the salt content of the deep wells in Iloilo and its environs is not decreasing, is clearly shown by the comparative data in Table I.

TABLE I.—*Chlorine content of artesian wells in Panay.*

[Numbers give parts per million.]

Well No.	Chlorine content by—	
	Previous analyses (1905–1913).	Latest analyses (Nov.–Dec., 1914).
452	792	855
471	695	750
500	797	810
511	866	870
514	831	870
530	1,520	1,660
568	1,791	1,800
428	726	790
Customhouse well No. 3	867	925
490	275	318
480	356	376
580	390	600

[2] *Water Suppl. & Irrig. Papers, U. S. Geol. Surv.* (1905), No. 151.

Although no great accuracy is claimed for the most recent analyses, since part of them were made by field methods, the results may be considered conclusive, especially as a number of determinations were checked volumetrically and showed good agreement. The detailed analyses of the artesian well waters of Iloilo and vicinity, as performed during the course of the present investigation, are given in Table II.

Color is rated in approximate accordance with the Hazen platinum-cobalt color standard.[3]

As will be seen from the analyses, the waters listed are all brackish.[4] Some of the artesian wells show an appreciable variation in their flow, being influenced by the tides; in fact, some are intermittent and flow only at high tide. The quality, too, of these waters, shows certain variations, but whether the changes noticed are also dependent on the tides has not yet been established. It is clear that seepage from the ocean is not a factor. The absence of sulphates is a marked peculiarity. Barber[5] has already pointed out that flowing artesian wells are practically sterile, and this series of tests confirms his conclusions. None of the drilled wells examined showed an excessive bacteria count.

In view of their high mineral content, their brackishness, their mildly laxative properties, and their excessive hardness, it does not seem advisable to try to develop any of these waters as a source of municipal supply.

MAASIN

The Maasin proposition involves the installation of the type of system which has already been found successful at Manila and Cebu; namely, the impounding of the water from a river and the reservation of the watershed drained by that river from settlement and trespass.

The advantages of the Maasin project are the certainty of an adequate supply of water throughout the year and the possibility of supplying other towns, between Maasin and Iloilo, with much-needed water systems; its disadvantages are the distance (at least 25 kilometers) which the water must be piped, and the cost of the enterprise (more than 2,000,000 pesos).

[3] *Am. Chem. Journ.* (1892), 14, 300.

[4] All the waters in Table II, with the possible exception of Nos. 7, 8, 13, and 15, and perhaps one or two others, were being used for drinking purposes. They are certainly more wholesome than any other natural waters available in the districts they supply.

[5] *This Journal, Sec. B* (1913), 8, 443.

TABLE II.—*Deep wells, Iloilo and vicinity.*

[Numbers give parts per million.]

Tracing No.	Laboratory "I" No.	Location.	Artesian well No.	Depth.	Flows or pumps (liters per minute).	Color.	Turbidity as SiO_2.	Chlorides (Cl).	Carbonates as Na_2CO_3.	Bicarbonates as $CaCO_3$.	Sulphates as SO_3.	Alkalinity as $CaCO_3$.	Iron (Fe).	Calcium (Ca).	Total hardness as $CaCO_3$.	Bacterial count, per cc.	Acid formers.	Gas formers.
				m.														
1	7	Provincial building, Iloilo	452	75	Flow slight or nil	(a)		355	0	28.6	0	28.6	6.0	80±	232	10	0	0
2	13	Calles Mabini and Gral. Luna, Iloilo	471	77	Pumps	1.5	0	750	0	43.0	0	43	4.0		206			
3	9	Public market, Iloilo	500	76	do	(a)	0	810	0	50.0	0	50	10.0		388			
4	8	Plaza Libertad, Iloilo	511	62	Flows only at high tide.		0	870	0	72.5	0	72.5	4.0		370			
5	3	Calle Ortiz, Iloilo	514	63	Flows 70			870	0	64.5	0	64.5	8.0	100±	296	0	0	0
6	10	Landon mess, Calle Remedios, Iloilo	523	87	Pumps	0.8	0	1,060	0	35.0	0	35.0	2.0		442			
7	20	Off Calle Rosario (M. Zerrudo)	530	73	do	0.7	0	1,660	0	32	0	32.3	4.5		192			
8	17	Plaza Goiti and Ledesma, Iloilo	568	72	do	0	0	1,800±	0	44.0	(a)	41.0	10.0		720			
9	11	Calles Lanao and Yznart, Iloilo	592	79	Flows 15	1.0	0	930	0	51.0	0	51.0	2.0		240	6	0	0
10	15	Calles Ledesma and Rizal, Iloilo	600	79	Flow slight	0.7	0	600	0	31.0	0	31.0	6.5		269	<40	0	0
11	12	Assumption College, Iloilo	428	77	Flows 19	1.5	0	790	0	31.0	0	31.0	4.0		234	0	0	0
12	19	Customhouse, Iloilo			Flows 10	0	0	925	0	50.0	0	50.0	4.0		320			
13	25	Iloilo Electric Co., Iloilo		78	Flows only at high tide.	1.0	0	1,280	0	50.0	0	50.0	12.0		323			
14	14	On proposed street near Calle Ledesma, Iloilo.		76	Flows 55	0.5	0	960	0	43.0	0	42.8	6.0		280	10	0	0
15	21	Calle Rosario, No. 26, Iloilo (J. Javellano)		120	Pumps	0.5	0	1,550	0	46.0	0	46.1	7.5		166			
16	5	Calles R. Mapa and Cementerio, Mandurriao	490	86	Pumps 110	3.5	0	318	34.8	12.5	0	37.5	2.5	20±	58.0	100±	20	0
17	1	Calles Nueva and Antigua, Molo	480	60	Flows 3.5±		0	376	0	89.5	0	89.5	2.2		230	10	0	0
18	2	Calle Antigua, near bay, Molo	580	54	Flows 35			600	0	72.5	0	72.5	1.0		400	10	0	0

[a] Trace.

From a chemical point of view, the water is potable, and since it comes from a sparsely settled watershed, which could be closed to settlement and guarded against trespass, it can doubtless be kept uncontaminated. The chemical analysis of the Tigon River water is as follows:

TABLE III.—*Chemical analysis of the Tigon River water.*

Physical characteristics	Normal.
Turbidity	Nil.
Color	Nil.
Total solids	390
Fixed	290
Volatile	100
Organic matter	Trace.
Alkalinity as $CaCO_3$	50
Iron (Fe)	0.7
Magnesium (Mg)	Little.
Normal carbonates as Na_2CO_3	Nil.
Bicarbonates as $CaCO_3$	50
Sulphates as SO_3	54
Chlorides (Cl)	16
Total hardness as $CaCO_3$	140
Estimated encrustants	140

GUIMARAS ISLAND

Guimaras Island is well supplied with water. In the coralline limestone formations near the coast there are many springs which have excellent local reputations; farther inland and upland there are streams which have an apparent abundance of clear soft water. During the Spanish régime, the waters from various springs were brought into great stone baths, some of which still exist.

The single attempt to drill an artesian well on Guimaras proved a failure. Although a depth of over 200 meters was attained, no potable water was encountered in any appreciable quantities.

Table IV shows the analyses of typical water supplies.

The "probable encrustants" were determined in accordance with the formula given by Dole.[6] The "classification for boiler use" is more or less arbitrary.

Chemically these waters appear to be suitable for the Iloilo supply. Guimaras Island is so sparsely populated that it should be very easy to prevent the contamination of any of the sources listed.

[6] *Water Suppl. & Irrig. Papers, U. S. Geol. Surv.* (1910), No. 254, 232.

TABLE IV.—*Waters of Guimaras Island.*

[Numbers give parts per million.]

Tracing No.	Laboratory "I" No.	Location.	Source.	Color.	Turbidity as SiO_2.	Chlorides (Cl).	Carbonates as Na_2CO_3.	Bicarbonates as $CaCO_3$.	Sulphates as SO_3.	Alkalinity a's $CaCO_3$.	Iron (Fe).	Total hardness as $CaCO_3$.	Probable encrustants.	Classification for boiler use.	Remarks.
1	26	Daliran, Buenavista	Spring	0	0	10.5	0	48.5	(a)	48.5	1.0	246	145	Fair	Less than 60 bacteria per cc.; no acid or gas formers.
2	27	Buenavista	Taingban Cave	0	0	9.0	0	46.2	(a)	46.2	4.0	300	171	do	
3	28	Near river at Buenavista	Spring	0	0	24.0	0	50.0	(a)	50.0	1.0	288	165	do	
4	29	Large cement bath, Nagaba	do	0	0	11.5	0	49.1	(a)	49.1	5.0	336	190	Fair to poor	
5	30	Old broken-down bath, Nagaba	do	0	0	13.0	0	50.0	(a)	50.0	5.0	335	188	do	
6	31	Eight kilometers from Nagaba southeast of hacienda.	Waterfall, river	0	0	8.0	0	25.0	(a)	25.0	1.0	40	32	Excellent	
7	32	Near hacienda	Spring	0	0	8.5	0	50.0	(a)	50.0	0.66	276	160	Fair	Fifty organisms per cc.; no acid or gas formers.
8	33	South of hacienda	River	0	0	6.5	0	17.0	(a)	17.0	0.85	46	31	Excellent	

[a] Trace.

At the present time weirs have been established to determine how much water is available from the various water sources at different seasons of the year. It is quite possible that enough water may be developed from the upland sources to enable the installation of a direct gravity system for Iloilo.

The Guimaras project is an attractive one, because, if feasible, it means a supply of water for Iloilo at comparatively low expense. The distance across the straits is something over 3 kilometers, but in spite of the added difficulty and expense involved in piping the water under the sea, the estimated cost of the Guimaras project is only about one-tenth that of the Maasin enterprise.

CONCLUSIONS

The chemical character of the artesian waters is such that their development as a source of municipal water supply does not seem advisable.

The Maasin and the Guimaras Island projects are both feasible, so far as the quality of the water is concerned.

ILLUSTRATION

TEXT FIGURE

FIG. 1. Map of Guimaras Island and a part of Panay Island, P. I.

73

BOILER WATERS OF ILOILO PROVINCE [1]

By George W. Heise

(*From the Laboratory of General, Inorganic, and Physical Chemistry, Bureau of Science, Manila, P. I.*)

A good illustration of the practical value of, and the necessity for, a systematic study of Philippine water supplies was furnished during the course of a recent field investigation of the waters available for the municipal supply of Iloilo, on Panay Island.

Iloilo, now numbering over 50,000 inhabitants, is one of the largest and most important cities in the Philippine Islands; yet it has no water supply system. Its needs are supplied for the most part by a number of brackish artesian wells, by surface wells, and by rain-water cisterns. The users of boiler water seem never to have been able to obtain waters suitable for their needs. Practically without exception, the waters extensively used at the present time are uniformly bad, and there have been developed no sources of good water within a reasonable radius of the city of Iloilo. The artesian wells of Iloilo and vicinity are almost out of the question for boiler use, owing to the excessive amounts of salt and scale-forming ingredients which they contain, and the surface supplies are almost as bad. A representative of one of the larger firms in Iloilo asserted that his company was spending 500 pesos a month for boiler parts and wear and tear on equipment, due to the use of bad boiler water. There was no apparent reason to believe that the figure mentioned was exaggerated, indicating that the waste due to the use of improper water for industrial purposes amounted to several thousand pesos per month for the city of Iloilo alone. Most of the boiler water used is taken from Salog River at Jaro, whence it is piped to Iloilo. Although known to be of very poor quality, it was the best water available, and was accordingly much used.

No systematic study of the available water supplies had ever been attempted. A preliminary investigation indicated that there must be sources of good water available for use in Iloilo Province either unknown or undeveloped. In the regular course

[1] Received for publication, January 26, 1915.

TABLE I.—*Analyses of waters of Iloilo Province.*

[Numbers represent parts per million.]

Tracing No.	Laboratory "I" No.	Location.	Source of supply.	Color.	Turbidity as SiO_2.	Alkalinity as $CaCO_3$.	Total solids.	Fixed solids.
1	31	Guimaras	Waterfall, 8 kilometers southeast of Nagaba.	0	0	25.0		
2	49	Dao, Capiz	Sump	100	(a)	33.4	230	100
3	62	Bridge 27-8, Philippine Rwy. Co	Slough	50	(a)	72.6	190	105
4	50	Buntog, Capiz	Panay River	100	29	34.4	125	85
5	64	At telegraph pole 15-10, Philippine Rwy. Co	Slough	50	25	51.7	120	30
6	53	Railroad bridge 56-9, Lamunang, Iloilo	Lamunang River			33.4	212	126
7	58	Crossing Passi-Calinog provincial road, Iloilo	do	0	0	50.0	260	140
8	48	Mambusao, railroad bridge 90-5	Mambusao River	25	0	50.0	230	160
9	59	Passi, Iloilo (above juncture with Lamunang River)	Jalaur River	0	(a)	30.8	190	110
10	55	Passi, Iloilo, railroad bridge 53-6	do		400	31.8	514	323
11	39	Golf Club, Santa Barbara, Iloilo	Spring	0	0	66.7		
12	60	Philippine Rwy. Co. bridge 46-6	Ulian River		(a)	46.2	260	170
13	34	Beyond Pototan, crossing of provincial road with river.	Jalaur River	0	0	54.5		
14	51	North of Dumarao, Capiz	Stream	25	0	47.5	310	215
15	52	Dumarao, Capiz	Sump	25	(a)	50.0	[illegible]	225
16	36	At river-crossing of provincial road between Santa Barbara and Janiuay.	Tigon River	0	0	[illegible]	[illegible]	220
17	61	Bridge 39-5, Philippine Rwy. Co	Abangay River	50	(a)	51.5	[illegible]	405
18	63	Bridge 17-4, Philippine Rwy. Co	Tigon River	0	(a)	51.7	425	315
19	45	Pototan, Iloilo	River	0	0	54.6	425	370
20	65	Pavia, Iloilo	Tigon River	0	0	41.6	[illegible]	285
21	46	Capiz, Capiz	Sump			46.8	[illegible]	420
22	56	Pavia bridge, Iloilo	River	0	0	26.4	[illegible]	560
23	23	Trade School, Iloilo	Surface well	0	0	[illegible]		

24	54	Passi, Iloilo	Sump	10	0	32.2	700	485
25	44	Calle Jaena, next to municipio of Pototan, Iloilo	Surface well	0	0	46.0		
26	16	Jaro, Iloilo	Salog River	0	0	32.0		
27	4	Near monument at Plaza Libertad, Iloilo	Surface well		0	54.5		
28	22	At army post, within 50 meters of the bay, Iloilo, Iloilo.	do	0	113	44.5		
29	37	At plaza, Santa Barbara, Iloilo	Artesian well	125	0	75.0	1,180	1,040
30	5	Calles R. Mapa and Cementerio, Mandurriao, Iloilo	Artesian well 490	175	0	37.5		
31	3	Calle Ortiz, Iloilo	Artesian well 514			61.5	2,260	2,005
32	25	Iloilo Electric Co., Iloilo	Artesian well	50	0	50.0		
33	10	Calle Remedios, Iloilo	Artesian well 523	40	0	35.0		
34	17	Plaza Goiti and Ledesma, Iloilo, Iloilo	Artesian well 568	0	0	44.0		

Tracing No.	Volatile on ignition.	Calcium (Ca).	Iron (Fe).	Sulphates as SO_3.	Chlorides (Cl).	Normal carbonates as Na_2CO_3.	Bicarbonates as $CaCO_3$.	Total hardness as $CaCO_3$.	Probable encrustants.	Classification for boiler use.	Remarks.
1		0	1.00	(a)	8.0	0	25.0	40	35	Excellent	
2	100	39	2.70	0	8.0	0	33.4	66	50	Good	Contains much organic matter.
3	85	(a)	2.00	(a)	11.0	0	72.6	68	75	do	
4	40	40	0.80	18.0	5.0	0	34.4	80	75	do	
5	90	(a)	4.00	0	19.0	0	51.7	52	55	do	Do.
6	84	(?)96	0.35	10.5	5.0	0	33.4	94	75	do	
7	120	81	0.50	10.0	7.5	0	50.0	100	85	do	
8	120	70	2.00	14.5	5.5	0	50.0	100	90	Fair	
9	80	(?)96	0.35	19.0	8.0	16.9	15.4	128	90	do	
10	186	83	2.70	15.5	6.5	0	31.8	100	80	do	Clears rapidly by sedimentation.
11		(?)100	0	(a)	8.0	0	66.7	131	100	do	
12	90		0.35	19.0	10.0	0	46.2	112	95	do	
13			0.50	29.0	10.0	0	54.5	120	115	do	
14	85		0.25	25.0	6.5	0	47.5	168	130	do	

[a] Trace.

TABLE I.—*Analyses of waters of Iloilo Province*—Continued.

Tracing No.	Volatile on ignition.	Calcium (Ca).	Iron (Fe).	Sulphates as SO_3.	Chlorides (Cl).	Normal carbonates as Na_2CO_3.	Bicarbonates as $CaCO_3$.	Total hardness as $CaCO_3$.	Probable encrustants.	Classification for boiler use.	Remarks.
15	80		1.50	27.5	11.5	0	50.0	152	125	Fair	
16	100		0.65	54.0	16.0	0	50.0	140	145	do	Contains some organic matter.
17	130		1.00	19.0	102.5	0	54.5	100	95	do	
18	120	110	0.50	22.5	14.0	0	51.7	250	170	Fair to poor	
19	35	(?)110	6.00	50.0	14.0	21.2	25.5	138	125	Fair	
20	80		2.00	79.0	17.0	19.3	25.0	146	155	do	
21	240		0.35	125.0	85.0	0	46.8	106	185	Poor	
22	80		(a)	100.0	16.0	0	36.4	192	200	do	
23			0	11.0	70.5	0	50.0	212	140	Fair	
24	215		0.35	68.5	117.0	0	32.2	193	170	Poor	
25			1.70	73.0	85.0	0	46.0	282	230	do	
26			0.30	144.0	154.0	0	32.0	306	340	Bad	
27			1.00	350.0	790.0	0	54.5	440	545	Very bad	
28			24.00	>600	8,150.0	26.5	19.4	820	1,020	do	
29	140	0	12.00	0	242.0	60.5	17.5	17	17	(?)	Too high in nonencrusting solids for good boiler water.
30		<20	2.50	0	318.0	34.8	12.5	55	35	(?)	Do.
31	255	119	8.00	0	570.0	0	64.5	296	185	Bad	
32			12.00	0	1,280.0	0	50.0	328	190	do	
33			2.00	0	1,060.0	0	35.0	442	240	Very bad	
34			10.00	(a)	1,835.0	0	44.0	720	390	do	Becomes turbid on standing.

[a] Trace.

of the work a number of water supplies were found which might be used to advantage, and in order to make the results of this work available the most significant data are tabulated herewith.

Most of this work was done in the field, for the most part in accordance with the methods outlined by Leighton,[2] by whom the sources of error and the accuracy of these methods have been discussed. "Color" is rated in terms of the Hazen[3] platinum-cobalt standard. The "probable encrustants" were calculated in accordance with the formula given by Dole.[4] The "classification for boiler use" is more or less arbitrary.

Although these data are only approximate, they give a fairly good idea of the industrial water supply situation in Iloilo, and indicate that there are a number of sources which will yield good boiler water.

Some of these waters should be quite suitable for boiler purposes without any treatment; most of them could be made into excellent boiler waters by preheating or by inexpensive chemical treatment. It will be noted that the "Jaro" water is one of the worst on the list. The sources listed for the most part are surface supplies; hence, it is possible that change of season might introduce or cause variations in chemical quality. All of the analyses were made in November and December, 1914; that is, after the dry season was well along; hence, another series of analyses should be made, preferably during the rainy season, to determine whether any changes occur great enough to affect the fitness of these waters for boiler purposes.

[2] *Water Suppl. & Irrig. Papers, U. S. Geol. Surv.* (1905), No. 151.
[3] *Am. Chem. Journ.* (1892), 12, 300.
[4] *Water Suppl. & Irrig. Papers, U. S. Geol. Surv.* (1910), No. 254, 232.

A PRELIMINARY CHECK LIST OF PHILIPPINE MINERALS [1]

By WARREN D. SMITH, F. T. EDDINGFIELD, and PAUL R. FANNING
(From the Division of Mines, Bureau of Science, Manila, P. I.)

The following 113 mineral species and varieties comprise all those known with certainty to us to occur in the Philippines. There are others whose presence we suspect, but which have not been definitely identified. For instance, tin, native brass, and diamonds are said to exist here, but this laboratory has no authoritative knowledge of them.

All the minerals herein mentioned are in the collections of the Bureàu of Science, and have been collected for the most part during the American régime. The collections of the old Spanish Mining Bureau were almost worthless when they passed into the hands of the Americans. Whether the best specimens had been transferred elsewhere at the outbreak of hostilities we do not know, but we have reason to suspect such to have been the case.

Three other mineral collections in the city of Manila have been consulted; namely, that of the Ateneo de Manila of the Jesuit Order, that of the Santo Tomás University of the Dominican Order, and lastly that of the Ateneo de Rizal, but we have found only a very few specimens which were not in our own collection. As there is some doubt also about the localities of some of the minerals in those collections, we have purposely omitted several species.

Our acknowledgement of assistance from the curators of these institutes is hereby gratefully made.

It will be noted that many of the minerals in the following list have no economic value, but the fact that a substance has no present commercial value is no reason for excluding it from a catalogue. The future will undoubtedly see a number of minerals now thought to be of little or of no use to man become of great commercial value. For instance, when the large deposits of concentrated iron oxides, like hematite and limonite, become exhausted we shall be forced in all probability to turn to the iron-bearing silicates of too low a grade to be worked economically at the present time. The mineral leucite with its 21 per cent of potash is a valuable prospective source of this important

[1] Reprinted from *Min. Resources P. I. for the year 1913, Bur. Sci.* (1914).

ingredient of the soil, but only until recently has any one thought seriously of extracting it.

We have before us the list of minerals of Taiwan (Formosa) by Okamoto, of the educational bureau of that island. In this list he gives 50 minerals, less than half the number we have in the following list. Six of these we have not yet found in the Philippines, while there are 3 others which we suspected to be here but have not certainly determined.

We take this opportunity to urge all the mining men and students of the various schools and colleges to send specimens of any minerals which they may think new or interesting to the Bureau of Science. It is reasonable to expect that when more persons shall become interested in this line and more observant of natural objects this list will be greatly augmented. We are already greatly indebted to many of our friends of the mining community for valuable specimens.

It is to be regretted that up to the present we have not made many studies of a mineralogic nature, as more pressing investigations in the mining fields have prevented us from doing so. The compilation of this preliminary list has suggested several subjects which can be profitably taken up in the future.

CHECK LIST OF PHILIPPINE MINERALS

Actinolite—$Ca(Mg, Fe)_3Si_4O_{12}$.

This mineral occurs as acicular green crystals in the crystalline schists of Ilocos Norte. It is classed as one variety of asbestos in the trade. There is no production in the Philippines.

Agate—SiO_2.

Agate is found in many parts of the Archipelago where silicification has occurred. Occasionally some specimens suitable for polishing are found. There is no production in the Philippines.

Albite. (See Plagioclase).

Altaite—PbTe.

This mineral occurs intimately mixed with sylvanite and free gold in specimens from the Tumbaga mine, Ambos Camarines. It is tin white, sometimes with a bronze tarnish, and occurs as negative crystals or pseudomorphs after quartz crystals or fragments. Development work exists only at this mine.

Amethyst—SiO_2.

Some large crystals have been found in Palawan, but this mineral is not common in the Philippine Islands. One large specimen of amethyst crystals from Mount Tumarbon, Palawan,

can be seen in the Santo Tomás Museum. When perfect it is used as a gem. There is no production in the Philippine Islands.

Analcite—$NaAl(SiO_3)_2+H_2O$.

This mineral occurs as an alteration product of leucite in some volcanic rocks of limited distribution in Masbate.

Andesine. (See Plagioclase).

Anorthite. (See Plagioclase).

Anthophyllite—$(Mg, Fe)SiO_3$.

This mineral is a variety of amphibole in long dirty white to brownish fibers, and is associated with serpentine and asbestos. It occurs in Ilocos Norte. In some cases it could be used as a substitute for asbestos. There is no production in the Philippines.

Apatite—$Ca_5(Cl, F)(PO_4)_3$.

Apatite occurs as large yellowish crystals in small amounts in metamorphic rocks near Pasuquin, Ilocos Norte, and also in minute crystals in many igneous rocks in the Philippine Islands. It is valuable for fertilizer if found in large enough quantities. There is no production in the Philippines.

Aragonite—$CaCO_3$.

The mineral is found so far in one locality, Talim Island, Laguna, in long clear crystals in vugs in basalt. It has no economic value.

Arsenic—As (metallic).

This mineral is deposited presumably from hot springs in the form of kidneys (reniform). It is found near Buguias, Mountain Province. There is no local use for arsenic.

Asbestos—$H_4(Mg, Fe)_3Si_2O_9$. (?)

Asbestos is associated with serpentine in Ilocos Norte. No first-grade asbestos has yet been found. It consists practically of longitudinal fibers. One small sample of cross fiber (see Chrysotile) is in our collection. There is no production in the Philippines.

Asphaltum—Complex series of hydrocarbons.

One small specimen was brought in from the Eastern Cordillera, Luzon, which is of doubtful authenticity.

Augite—$(Mg, Fe)(Al, Fe)_2SiO_6$.

This mineral is one of the pyroxene group of silicates—common as a rock mineral. Augite has no economic value at present.

Azurite—$Cu_3(OH)_2(CO_3)_2$.

Azurite occurs as minute blue crystals in some copper deposits of Pangasinan, Batangas, and Mindanao.

Baltimorite—$H_4Mg_3Si_2O_9$.

Baltimorite is a white to bluish fibrous mineral associated with serpentine. It is found in Ilocos Norte. It could be used for steam packing and roofing material. There is no production in the Philippines.

Barite—$BaSO_4$.

Barite is reported from Mancayan as a vein mineral by A. J. Eveland.

Basonite—SiO_2.

This mineral is a velvet-black variety of flint known as "touch stone" or lydian stone. It could be used for testing the purity of gold. One sample, No. 176, is in the collection of the Ateneo de Manila.

Beryl (**emerald**)—$Be_3Al_2(SiO_3)_6$.

Small and imperfect specimens are reported from Mindanao, but nothing definite is known regarding the locality.

Biotite—$(H, K)_2(Mg, Fe)_2Al_2Si_3O_{12}$.

Biotite occurs in various igneous rocks in the Philippines in small crystals, principally in Paracale granite. No economic deposits are known here.

Bituminous coal—Complex composition, principally oxygenated hydrocarbons.

Bituminous coal is found in seams from a few centimeters to several meters thick in Cebu and Mindanao. Formerly there was a moderate production in Cebu. There is none in Mindanao. One specimen from Dumanquilas Bay, Mindanao, shows columnar structure.

Bornite—Cu_5FeS_4.

Bornite occurs massive to finely crystalline in quartz veins. It is probably secondary in origin. This mineral is found in several of the copper deposits in the Islands. An excellent sample comes from Quien Sabe claim, Suyoc, Mountain Province. There is development work in the Philippines but no production.

Calcite—$CaCO_3$.

Calcite is generally massive without crystalline faces, but some splendidly crystallized samples of "dog tooth" spar have

been found. It is frequently associated with primary and secondary manganese minerals, and is also frequently associated with quartz in ore veins, there being a progression from quartz to quartz-calcite, probably the result of lowering of temperature and pressure. Calcite occurs also as a secondary mineral in igneous rocks; also, as stalactites, stalagmites, and travertine. Marble is found in Romblon and crystallized limestone at Montalban. The mineral is used to manufacture quicklime for sugar refining. Marble is used for monuments and building purposes.

Chalcedony—SiO_2+H_2O.

Chalcedony occurs in irregular milky white patches in jaspers and other rocks in various parts of the Islands.

Chalcocite—Cu_2S.

Chalcocite is a massive gray mineral usually secondary in the upper zones. It is found in Misamis, Mindanao, and Mountain Province, Luzon. There is no production in the Philippines.

Chalcopyrite—$CuFeS_2$.

Chalcopyrite is the most universally distributed ore of copper. It is found as small crystals in a large number of quartz veins, and is associated mainly with galena and usually crystallizes after galena. It is found in small quantities in all of the mining districts. No commercial deposits are known in the Philippines.

Chert—SiO_2.

Chert occurs as nodules in various formations in many parts of the Archipelago, also as radiolarian cherts, probably of Jurassic age. It is well developed in Palawan, Panay, Ilocos Norte, and Balabac, and is probably equivalent to the radiolarian "hornfels" of central Borneo. It has no economic use.

Chlorite—$H_8Mg_5Al_2Si_3O_{18}$.

Chlorite occurs as fine, green fibrous masses as an alteration product in many igneous rocks. It has no economic use.

Chromite—$FeOCr_2O_3$.

Chromite occurs associated with serpentine in heavy granular masses with mottled black and green appearance in Antique Province, Panay. There is some prospecting but no production.

Chrysoprase—SiO_2 (colored by nickel oxide).

Chrysoprase occurs as beautiful leek-green pebbles in a river near Butuan, Mindanao. One specimen, No. 180, is in the collection of the Ateneo de Manila. This mineral could be used as a gem.

Chrysotile—$H_4(Mg, Fe)_3Si_2O_9$.

Chrysotile occurs as white to greenish silky fibers. Some inferior specimens have been found in Ilocos Norte. Short cross fibers of from 2 to 3 centimeters in length have been found. There is no production, but indications are promising.

Cinnabar—HgS.

Minute red crystals of cinnabar were found in a few samples from Batwaan Creek, Benguet, Luzon. Cinnabar remains in the pan with the gold. It is reported from Mount Isarog, Ambos Camarines. This mineral forms under surface conditions, and is connected with volcanic activity. It is not mined in the Philippines.

Copper—Cu (metallic).

Native copper occurs as irregular, partly crystalline masses and as round shot in alluvium; there are 3 type occurrences: (1) Amygdoloids in extrusives, in Masbate; (2) in alluvials of Malaguit River, Ambos Camarines; (3) reported in some quartz veins in Masbate. Native copper was probably used formerly by Igorots to make pots. It is not used at present.

Corundum—Al_2O_3.

Corundum occurs as pebbles in placers in Nueva Ecija, Luzon.

Crocoite—$PbCrO_4$.

Crocoite occurs in characteristic small orange-red monoclinic crystals in Labo, Paracale district, Ambos Camarines, Luzon. It is associated with galena-bearing rocks, and is not abundant.

Cuprite—Cu_2O.

Cuprite occurs as small clear red crystals in the surface ore of a copper deposit in Antique Province, Panay.

Diallage—A nonaluminous pyroxene.

Diallage is a common constituent of gabbros in the Philippines. It has no economic value.

Enargite—Cu_3AsS_4.

Enargite is probably secondary in copper deposits. It occurs massive and in small gray crystals with luzonite in the old Santa Barbara mine at Mancayan, Lepanto, Luzon. It is mined and smelted by Igorots. Formerly there was a considerable production by a Spanish company; at present it is not important.

Epidote—$HCa_2(Al, Fe)_3Si_3O_{13}$.

Epidote is very rare. It occurs as yellowish grains or in more

or less amorphous masses in a few igneous rocks. It has no economic value.

Galena—PbS.

Galena is found in veins only. It is lacking in the walls. Galena was formed generally later than pyrite. As a rule, it is crystallized. It is associated with zinc and pyrite in quartz veins, rarely in calcite veins. It frequently carries silver, but rarely gold. It is nearly always primary. Galena is resistant to decomposition. This mineral is found in veins in Suyoc, Mountain Province; in Batangas; Cebu; Marinduque; Paracale; and Surigao. During the Spanish régime galena was mined to a limited extent in Cebu, but is not mined at the present time.

Garnet—Complex silicates with Fe, Mg, Mn, and Ca as interchangeable bases.

The common species, andratite, occurs rarely in the Philippines as minute wine-red granules in a rock from Bulacan, Luzon. It has no economic value.

Gilsonite—Complex hydrocarbon.

Gilsonite is found in the northern part of Leyte Province adjacent to petroleum seeps in Miocene shale and sandstone. There is no production in the Philippines, but the Leyte deposit is being explored.

Gold—Au (metallic).

Gold occurs associated with pyrite and rarely with galena. It usually occurs as metallic gold in quartz and in calcite veins as wires, plates, grains, and crystals; abundantly distributed in placer as perfect crystals, wires, and rounded grains; and is occasionally found as nuggets weighing from 10 to 30 grams. Traces of gold are found in most rocks carrying pyrite. Gold is found in paying quantity in veins in Suyoc and Baguio, Mountain Province; Paracale and Mambulao, Ambos Camarines; and Aroroy, Masbate. It is found in paying quantity in placer in Suyoc, Mountain Province; Peñaranda district, Nueva Ecija; Umaeri, Tayabas; Paracale, Mambulao, and Malaguit, Ambos Camarines; Cansuran, Surigao; Hibong River, and other localities along the Agusan River, Mindanao; in Misamis Province; and in Mindoro.

Graphite—C.

Graphite is reported as occurring in "graphite clay" in Bulacan.

Guano—P_2O_5 with impurities.

Guano occurs as a coarse brownish earth in limestone caves in many parts of the Archipelago, principally along sea coasts. A small amount is collected, which is sold to Japanese exporters.

Gypsum—$CaSO_4$.

Gypsum occurs generally in small tubular crystals as incrustations on volcanic rocks near solfataras; also, in finely granular form in the Loboo Mountains, Batangas, Luzon. There is no production, and the quantity is apparently limited.

Hematite—Fe_2O_3.

Hematite is found in irregular "pockets" with magnetite, pyrite, chalcopyrite, and quartz in crystalline rocks of the Eastern Cordillera of Luzon; also, in veins cutting limestone. It occurs from Mambulao Bay, Ambos Camarines, to northern Bulacan, Luzon. The grade of this ore is excellent. It is smelted by Filipinos in crude blast furnaces to make plowshares.

Hornblende—$RSiO_3$, R being more than one of the elements Ca, Mg, Fe, Al, Na, and K.

Hornblende is abundant in many igneous rocks as black crystals varying in size from microscopic to 2 or 3 centimeters in length. It is of no economic value.

Hypersthene—$(FeMg)SiO_3$.

Hypersthene occurs in certain varieties of andesite in many localities. It is distinguished by its pleochroism (colorless to delicate pink) under the microscope. Hypersthene has no economic value.

Iddingsite—Exact composition not known.

Iddingsite occurs as alteration of olivine in rocks from three localities, Mount Mariveles, Bataan; Mindoro; and Batanes. The mineral is red. It has no economic value.

Ilmenite—$(Mg, Fe)TiO_3$.

Ilmenite is found in black-sand concentrates in many streams throughout the Archipelago, usually in small crystals and more or less rounded grains. It is not utilized.

Iridium—Ir (metallic).

The occurrence of iridium is the same as osmium.

Jasper—SiO_2.

Jasper occurs in fissile beds and in irregular masses. It contains remains of radiolarian tests. The color is brown to deep red.

Kalinite (alum)—$K_2SO_4 . Al_2(SO_4)_3+24H_2O$.

Kalinite occurs in mealy crusts around solfataras at Taal Volcano and elsewhere; apparently in small quantities.

Kaolinite—$Al_2O_3 .2SiO_2 .2H_2O$.

Kaolinite occurs in the Philippines usually as a solfataric decomposition product of andesitic rocks; it is rarely pure. In the region around Laguna de Bay, Luzon, it is found in irregular "pockets." Kaolinite is used to a moderate extent in making pottery and for a local paint, so-called "yeso," which is the Spanish equivalent for gypsum.

Labradorite—(See Plagioclase).

Leucite—$KAl(SiO_3)_2$.

Leucite occurs partially altered in certain very limited exposures of volcanic rock in the Aroroy district, Masbate. These rocks have from 8 to 10 per cent of potash, which might be made available for fertilizer.

Lignite—Various hydrocarbons.

Lignite is found in seams from 1 centimeter to 5 centimeters thick in many parts of the Archipelago. It usually crumbles into small cleavage cubes and air slacks. Its woody texture is seen best in weathered specimens. This mineral has been mined in the past, but there are no operations now.

Limonite.—$2Fe_2O_3 .3H_2O$.

Limonite is associated with hematite and is found near the surface; it occurs also in small pisolitic granules. It is distributed in small amounts throughout the Archipelago. Sometimes limonite is used in small quantities for paint.

Luzonite—Cu_3AsS_4.

Luzonite [1] is apparently a secondary ore of copper, and it is a special form of enargite. It forms in vugs and cracks in the vein. Luzonite is found in Mancayan, Mountain Province, and constitutes a large percentage of the enriched portion of the veins.

Magnesite—$MgCO_3$.

Magnesite occurs associated with serpentine in Ilocos Norte as a white, earthy mineral, which is efflorescent. No use is made of it.

[1] Moses, *Am. Journ. Sci.* (1905), 277.

Magnetite—Fe_3O_4.

Magnetite is widespread in small particles throughout the igneous rocks in the Philippines. It is also associated with the hematites of the Eastern Cordillera, Luzon. Fine octahedral crystals (No. 319) from San Miguel de Mayumo, Bulacan, Luzon, are in the collection of the Ateneo de Manila.

Magnetized iron ore—Lode stone. Apparently iron oxides.

This ore is found near Paracale, Camarines, and is also reported near Casiguran, Tayabas. No deposits are worked.

Malachite—$(Cu. OH)_2CO_3$.

No large crystalline samples of malachite are on record. This mineral is present in most of the copper deposits as a green coating.

Manganite—$MnO(OH)$.

Manganite occurs possibly with wad or pyrolusite in mineral veins, and often contains high values in gold. It is soft, and is derived from other manganese ores. It is found in several veins in Baguio and Suyoc, Mountain Province, and in Aroroy, Masbate. It has no economic value in the manner of its occurrence in the Philippines.

Marcasite—FeS_2.

Marcasite is similar to pyrite, but is whiter. It is apparently infrequent. Marcasite has been reported from Mancayan, Luzon.

Margarite—$H_2CaAl_4Si_2O_{12}$.

Margarite is a white mica occurring in certain schistose rocks of Ilocos Norte. No use is made of it, nor is there any production.

Mercury—Hg (metallic).

Mercury is reported to occur in small crevices and pockets on Mount Isarog, Albay, Luzon. A small phial of it is in the museum of the Ateneo de Manila.

Minium—PbO.

A large amorphous pink specimen of this mineral is in the museum of Santo Tomás University, marked "Filipinas;" no other data are given.

Molybdenite—MoS_2.

Molybdenite is found in characteristic form in steel-blue flakes and leaves in quartz veins, Loboo Mountains, Batangas Province, Luzon. Only a small amount is found.

Muscovite—$K_2O.3Al_2O_3.2H_2O$.

Muscovite occurs rarely in igneous rocks. It occurs more commonly in schists, particularly in a quartz muscovite schist in Ambos Camarines. There are no economic deposits of this mineral in the Philippines.

Niter—KNO_3.

Niter is said to be collected from certain caves on a small island near Surigao, Mindanao, and is used by natives for making gunpowder. This laboratory has no definite information regarding this substance in the Philippines, and its occurrence is to be doubted because of the heavy rainfall here.

Oligoclase—(See Plagioclase).

Olivine—$(Mg, Fe)_2SiO_4$.

Olivine occurs in many rocks in the Islands, particularly in small greenish yellow grains in basalt and in so-called picrites of Panay. It is of no economic value.

Opal—SiO_2H_2O.

Opal is found in small fragments, and occasionally in large pieces of jasper. It occurs in Ilocos Norte and various other localities, but is not of any commercial value as found in the Philippines. One pretty specimen showing "fire" is in the museum of Santo Tomás University.

Orthoclase—$K_2O.Al_2O_3.6SiO_2$.

Orthoclase occurs sparingly in some igneous rocks. It is of no economic use.

Osmium—Os (metallic).

Osmium occurs with gold, iridium, and traces of platinum in thin metallic plates in decomposed rock. The locality where the mineral is found is said to be Luzon.

Petroleum—Complex series of hydrocarbons.

Petroleum occurs as a very light, paraffin-base oil in shales in various parts of the Islands, notably in Bondoc Peninsula, Tayabas, Luzon, and in Cebu. Two wells, one shallow and one deep, have yielded a small amount of oil.

Philippsite—$(K_2, Ca) Al_2Si_4O_{12}+4\frac{1}{2}H_2O$.

Philippsite occurs in characteristic white, radiating or tuffed masses in Masbate. No economic use is made of it.

Pickeringite (magnesia alum)—$MgSO_4.Al_2(SO_4)_3+22H_2O$.

Pickeringite is found in long fibrous masses as efflorescence

in the old Santa Barbara copper mine, Mancayan (Lepanto), Mountain Province, Luzon; it also occurs on Camaguin Island, north of Luzon.

Plagioclase—($NaAlSi_3O_8$ to $CaAl_2Si_2O_8$).

This series of closely related minerals is one of the commonest of all the constituents of igneous rocks in the Philippines. It embraces the following species: Albite, anorthite, andesine, and labradorite. It has no known economic value as such.

Platinum—Pt (metallic).

Platinum is found in minute flattened grains in placer-test borings near Peñaranda in Nueva Ecija; on the Mariquina River in Rizal Province, Luzon; and in Agusan Valley, Mindanao. There is no production in the Philippines.

Prochlorite—$H_4(Mg, Fe)_2Al_2SiO_9$.

Prochlorite occurs in dirty green leaves which are flexible but not elastic. It is found in the metamorphic area of Ilocos Norte, Luzon. No use is made of it.

Psilomelane—H_4MnO_5. The manganese is commonly replaced in part by barium or potassium.

Psilomelane occurs associated with pyrolusite. It is a very impure ore of manganese, often containing only 40 per cent of manganese (see Pyrolusite).

Pyrite—FeS_2.

Pyrite occurs both massive and crystalline. The mineral appears as disseminated grains and as large crystals. Pyrite is often cupriferous. It is persistent in quartz veins and occasionally in calcite veins. Frequently it is one of the early minerals to crystallize. It is often associated with galena and zinc, but generally precedes them. Pyritization of vein walls occurs by reaction of the magnetite with H_2S gas from the fissure. Frequently this mineral is disseminated in volcanic rocks. Specimens of large secondary (?) crystals are in the Bureau of Science collection from Malaguit River, Camarines. Pyrite forms under conditions ranging from deep to surface. It is the most widely distributed metallic mineral. It is found in almost all rocks. This mineral is especially abundant in quartz veins, and is frequently associated with gold. There is no commercial use of pyrite in the Philippines.

Pyrolusite—MnO_2 with 2% H_2O.

Pyrolusite is the principal ore of manganese in the Philippines.

It occurs in botryoidal or massive shapes; also, reniform. It is found as veinlets in andesite and as nodules from erosion of veins and possibly in beds. It is found in Ilocos Norte, Pangasinan, Bulacan, Tarlac, and Masbate. It is not exploited.

Pyroxene—Ca (Mg, Fe) Si_2O_6.

Pyroxene is a common constituent of pyroxene andesite, one of the chief rock types in the Islands. It occurs in small jet-black crystals. It has no economic value.

Quartz—SiO_2.

Quartz is very persistent under conditions from deep seated to surface. It occurs in fine crystals in vugs under proper conditions; otherwise, it generally takes the form of jasper, chert, or siliceous sinter at the surface. It occurs in veins and as silicification of wall rocks. Two workable deposits only are known: (1) Siliceous spring deposits, Baguio, and (2) beach sand, Looc, Lubang Island. Quartz is used locally for road material and concrete in Baguio and at Looc.

Realgar—AsS.

Realgar occurs as characteristic red crystals on a yellow coating of orpiment on pieces of slag (?) from the old Santa Barbara furnace at Mancayan, Luzon. As far as we know it does not occur in a natural state in the Philippines. Specimens, No. 59, of realgar are in the museum of the Ateneo de Manila.

Rhodochrosite—$MnCO_3$.

Rhodochrosite occurs as a gangue mineral in auriferous calcite veins of Benguet. It is a primary mineral; it was probably leached from wall rocks by the ascending solutions and was later deposited with the calcite. Rhodochrosite is of no economic use.

Rutile—TiO_2.

Microscopic crystals occur in some of the metamorphic rocks from Ilocos Norte associated with actinolite, muscovite, etc. Rutile has no economic value.

Salt—NaCl.

Salt is deposited as incrustation from brackish carbonated springs in Mountain Province, Luzon, notably at Asin. It is used by the Igorots.

Sanidine—(K, Na) $AlSi_3O_8$.

Sanidine occurs in small crystals and grains. This "glassy feldspar" is a dominant constituent of the andesites of many

peaks in Zambales Mountains and of Mount Apo, Mindanao. It is of no economic value.

Sardonyx—SiO_2.

A specimen of this, No. 174, from Baganga, Mindanao, is in the collection of the Ateneo de Manila.

Sericite—$3Al_2O_3.6SiO_2.2H_2O$.

Sericite is one of the micas occurring in the schists of Ilocos Norte and Zamboanga Peninsula, Mindanao. It occurs in small gray-blue silky flakes. It is of no economic use.

Serpentine—$H_4(Mg, Fe)_3Si_2O_9$.

Serpentine, associated with pyroxenites and peridotites in more or less structureless masses, is found in Ilocos Norte and other localities. It is a greenish mineral. It occurs usually as asbestiform minerals. There is no production in the Philippines.

Silvanite—$(AuAg)Te_2$.

Silvanite occurs intimately mixed with the lead telluride altaite in quartz and calcite stringers in a contact between a slaty formation and a feldspar-porphyry dike.

Silver—Ag (metallic).

Silver occurs in the Philippines only in natural alloys with gold, and associated with the mineral galena. The gold from both placers and lodes in the Philippines carries silver varying in quantity up to 30 per cent. Silver-bearing galena is found at Panopoy, Cebu, and near Paracale, Camarines.

Sphalerite—ZnS.

Sphalerite occurs massive or as small crystals, always associated with lead and pyrite. Like the other sulphides, it favors the quartz veins; it forms under conditions of moderate depth. It is found in practically all localities where galena is found (see Galena). Sphalerite is not found in economically valuable quantities in the Philippines, although widely found in many veins. It is not utilized.

Stibnite—Sb_2S_3.

Stibnite occurs in characteristic fibrous masses. There is only one specimen in the Bureau of Science collection from Batangas Province, Luzon.

Sulphur—S.

Sulphur occurs more or less pure in characteristic yellow crystals around solfataras and also in a very impure state mixed with volcanic ash on Camiguin Island north of Luzon; on Taal Volcano and in Sorsogon, Luzon; on Mount Apo, Mindanao; and on Biliran Island. No sulphur is mined at present, but some mining was carried on formerly on Biliran.

Talc—$3MgO.4SiO_2.H_2O$.

There are small amounts of talc associated with mica and actinolite in the metamorphic region of Ilocos Norte, Luzon. No local use is made of this mineral.

Tetrahedrite—$4Cu_2S.Sb_2S_3$.

Tetrahedrite occurs as flint-gray to tin-black crystals. It is found at the old Santa Barbara mine, Mancayan, Lepanto, Luzon.

Titanite—$CaTiSiO_5$ or $CaO.TiO_2.SiO_2$.

Titanite occurs as characteristic wedge-shaped crystals associated with the iron-ore deposits of Bulacan.

Topaz—$(AlF)_2SiO_4$ or $(Al(F, OH)_2)SiO_4$.

Topaz occurs in small (2-4 millimeters) pink, yellow, and colorless orthorhombic crystals. It is found in placers of Paracale River, Ambos Camarines.

Tremolite—$CaMg_3(SiO_3)_4$.

Tremolite occurs in long white to greenish fibers associated with serpentine and asbestos in Ilocos Norte. It could be used commercially.

Uralite—Composition same as pyroxene save for slight change in magnesium and calcium content.

Uralite is a green alteration product of pyroxene, and is found in certain igneous rocks called metadiorites, which are altered gabbros.

Vermiculite—Hydrated mica.

Vermiculite is an earthy mica found in the metamorphic area of Ilocos Norte. It has no economic value.

Wad—An earthy mixture of manganese oxides.

Wad is found in association with psilomelane and pyrolusite. It is of no economic importance now.

Wernerite—Intermediate between $Ca_4Al_6Si_6O_{25}$ and $Na_4Al_3Si_9O_{24}Cl$.

Wernerite is a white fibrous silicate, and occurs in veinlets in greenstone in Aroroy district, Masbate. No economic use is made of it.

Wolframite—$(FeMn)WO_4$.

Wolframite is a heavy, black, crystalline mineral. Specimens are said to have been found in Antique Province, Panay. There is no economic development.

Zeolite—Composition is uncertain. $RAl_2Si_{10}O_{24}$.

Zeolite occurs as a fibrous secondary product in the decomposition of certain rock minerals, principally feldspars, and in amygdoloidal cavities throughout the Islands. This mineral has no known use.

REVIEWS

A Laboratory Guide | to the Study of | Qualitative Analysis | based upon the | application of the theory of | electrolytic dissociation | and the law of mass action | by | E. H. S. Bailey, Ph.D. | professor of chemistry | and | Hamilton P. Cady, Ph.D. | associate professor of chemistry in the University of Kansas | seventh edition | Philadelphia | P. Blakiston's Son & Co. | 1012 Walnut Street | 1914 | Cloth, pp. i–x+1–280. Price, $1.25 net.

The seventh edition of Professors Bailey and Cady's book is essentially the same as the sixth edition except that the alternative method for the treatment of the cations of groups III and IV which was an appendix in the sixth edition is in the present one incorporated in the body of the text.

The book contains a brief and accurate discussion of electrolytic dissociation and the mass law as applied to qualitative analysis; experiments and tables for the separation of cations and anions into groups and their identification; while such subjects as, hydrolysis, rules for oxidation and reduction, etc., are treated in their proper places in the book thereby making it easy for the student to comprehend their practical application. A table of solubilities closes the text. It is an excellent work for students of qualitative analysis in scientific schools of the Philippine Islands.

T. DAR JUAN.

The Source, Chemistry | and | Use of Food Products | by | E. H. S. Bailey, Ph.D. | professor of chemistry and director, Chemical Laboratories, | University of Kansas | author of "A system of quantitative analysis"; "Sanitary and | applied chemistry," etc. | with 75 illustrations | Philadelphia | P. Blakiston's Son & Co. | 1012 Walnut Street | No date, copyright, 1914. Price $1.60 net.

The Source, Chemistry and Use of Food Products by E. H. S. Bailey of the University of Kansas is a book well adapted as a supplementary text in a high school or college course in agriculture or a course in dietetics.

It is a simple, readable, elementary text on the source and use of food products, containing numerous tables of the nutritive value of the foods described. It does not contain enough data on the chemistry of foods to be a complete text in this subject for college students; however, when supplemented by lectures it would be very valuable as reference reading.

The headings and subheadings are somewhat confusing because of their arrangement and frequency and we believe the appearance of the book would have been benefited by the adoption of a different system and by making fewer subheads. The data on any one particular food are also rather scattered and a closer correlation of this information would have resulted in an improved text. Many source references are given, which is a commendable feature, and while the references are limited in scope, they are the ones that are most apt to be available to the ordinary high school and college.

On the whole, the book is written in an interesting fashion, can be easily read by a person without a knowledge of chemistry, and, while it offers no new information on the subject of foods, is valuable because of its availability to the nontechnical person.

H. C. B.

THE PHILIPPINE

JOURNAL OF SCIENCE

A. CHEMICAL AND GEOLOGICAL SCIENCES AND THE INDUSTRIES

VOL. X MARCH, 1915 NO. 2

PROPOSED MODIFICATION OF YLANG-YLANG OIL STANDARDS [1]

By H. D. GIBBS

(*From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.*)

The ylang-ylang (*Canagium odoratum* Baill.), a medium-sized to rather large tree, is a native of the Malay Archipelago and has been introduced into many other tropical countries for commercial and ornamental purposes.

The essential oil is obtained from the flowers in the Philippine Islands, Indo-China, Java, Siam, New Caledonia, Jamaica, German East Africa, and a number of islands in the vicinity of the last country: namely, Madagascar, Mayotte, Nassi-Bé, and Réunion. The greatest commercial success has been attained in the Philippines and in Réunion on account of the high quality of the product. France takes the largest part of the oil produced in these two places.

The exports for the last five years from the Philippine Islands are given in Table I.

TABLE I.—*Oil exported from the Philippine Islands during the years 1909–1913.*

Year.	Amount.	Value.	
		Total.	Average per kilogram.
	Kilos.	*Pesos.* [a]	*Pesos.* [a]
1909	2,812	175,872	62.54
1910	1,878	116,668	62.12
1911	1,684	94,808	56.30
1912	2,785	161,758	58.08
1913	2,172	116,618	53.70

[a] One peso Philippine currency equals 50 cents United States currency.

[1] Received for publication January 28, 1915.

The figures for the production prior to 1909 have been tabulated by Bacon.[2] They are considered to be unreliable.

Table I indicates that the foreign sale of ylang-ylang has fallen off and that the average price per kilogram has decreased. The decline is undoubtedly due in part to the competition of other countries, resulting in a diminished demand for second- and third-grade oils. The improved quality and the recent low price of ylang-ylang flowers have also largely eliminated the poorer grades of oil from the local market.

The chemical constituents and chemical properties of ylang-ylang oil have been the subject of numerous investigations.[3] Various attempts have been made to prepare an artificial oil which would displace the true ylang-ylang oil; but on account of the decrease in price of genuine ylang-ylang oil and its real superiority, these attempts have met with very little success.

Bacon [4] found that an oil with a low refractive index, low optical rotation, and high ester number is almost certain to be good; while high refractive index, high optical rotation, and low ester number indicate a poorer grade oil. He states that the ester number of first-grade oils is usually 100 or more, the refractive index is rarely over 1.4900 at 30°, and the optical rotation varies from —32° to —45°, the latter depending on the proportion of sesquiterpenes present. These constants are given in Table II.

TABLE II.—*Classification of ylang-ylang oil according to Bacon.*

Constants.	First grade.	Second grade.
Ester number	100 and above	80 to 100.
Index of refraction	1.4900 and below	Above 1.4900.
Specific rotation	—45° and below	Above —45°.

Two years later Bacon reports [5] that owing to a reduction in the price of flowers to 7 centavos (3.5 cents United States currency) per kilogram better flowers were obtainable, and because of the adoption of improved methods in distillation, oils having an ester number of from 130 to 150 were common.

[2] *This Journal, Sec. A* (1908), 3, 65.

[3] Gal, H., *Compt. rend. Acad. sci.* (1873), 76, 1482; Flückiger, *Arch. d. Pharm.* (1881) (3) 18, 24; Reychler, *Bull. Soc. chim. Paris* (1894), 11, 407, 576, and 1045; Dareus, Ibid. (1902), 27, 83; Schimmel & Co., Semi-annual report (October, 1901), 53; D. R. P. (September, 1901), 142, 859; Bacon, *This Journal, Sec. A* (1909), 4, 130; and (1910), 5, 265.

[4] *This Journal, Sec. A* (1908), 3, 65.

[5] Ibid. (1910), 5, 265.

This improvement in quality has continued as evidenced by the constants compiled from data obtained from the oils examined by this laboratory, and given in Table III.

TABLE III.—*Yearly average of constants of ylang-ylang oil for 1910–1914.*

Constants.	Average for—				
	1910	1911	1912	1913	[a] 1914
Ester number	114.3	111.0	112.6	122.3	133.2
Index of refraction	1.4918	1.4900	1.4876	1.4925	1.4853
Specific rotation degrees	−27.3	−25.7	−32.4	−20.7	−18.9

[a] To July 1, 1914.

Measured by Bacon's standard, the average for each year tabulated in Table III has shown a rise in quality over the averages for the years preceding it. This advance in quality is indicative of the fact, referred to above, of the improvement made by the adoption of better methods in handling and distilling.

In the light of the above tabulation I believe the time is opportune for the introduction of a few changes in the standards for the classification of ylang-ylang oil. Therefore I propose the adoption of a table introduced by Doctor Jahrling of the firm of Santos and Jahrling of Manila. Table IV gives these constants as published by Jahrling.[6]

TABLE IV.—*Classification of ylang-ylang oil according to Jahrling.*

Grade.	Ester number.	Index of refraction.	Specific rotation.	Soluble in alcohol of—
			°	*Per cent.*
Extra	>145	<1.4900	<−35	80
1 a	>120	<1.4950	<−48	90
1 b	>100	<1.4990	<−60	90–96
2	<100	>1.4990	>−60	96

This table really divides what was formerly classed under Class I into three divisions: namely, Extra, 1a, and 1b, depending on the constants shown by the oil. I believe this to be a fair extension of the grading proposed by Bacon, since it makes a distinction among the really high-grade oils and gives the man with an extra-quality oil credit for his efforts.

Schimmel & Co.[7] state that in their experience the best oils have a range of constants as given in Table V.

[6] *Rev. gén. chim.* (1913), 16, 43.

[7] Bericht von Schimmel & Co. (October, 1913), 108.

TABLE V.—*Constants of Schimmel & Co.'s best oils.*

Ester number	75 to 120
Index of refraction	1.4910 to 1.5000
Specific rotation	—37° to —57°
Specific weight	0.930 to 0.945

Schimmel & Co. reject the solubility in alcohol as a test for classification. I have found this test very useful as a confirmatory test, since it indicates the amount of sesquiterpenes present in the oil; therefore I have adopted it for use as a standard for classification in this laboratory. This test consists in determining the lowest strength of aqueous alcohol which can be mixed with the oil without cloudiness in the proportion of 2 of oil to 1 of alcohol. Oils with constants superior to those given by Schimmel & Co. are common in the Philippine Islands.

Table VI is a list of constants taken at random from the data collected by the Bureau of Science on the oils examined from January 1, 1913, to July 1, 1914. The table also gives the grade of the oil, classified according to Jahrling's method.

TABLE VI.—*Constants of some samples of ylang-ylang oil examined by the Bureau of Science.*

Grade.	Ester number.	Index of refraction.	Specific rotation.	Specific gravity.
			°	
Extra	150.73	1.4875	—18.10	0.9509
1 a	133.50	1.4920	—25.90	0.9420
1 b	112.70	1.4935	—32.20	0.9349
1 a	139.06	1.4900	—24.40	0.9432
1 b	115.20	1.4975	—46.20	0.9255
1 a	136.90	1.4940	—31.80	0.9457
Extra	154.90	1.4890	—19.04	0.9519
1 a	141.50	1.4835	—23.80	0.9292
1 a	135.20	1.4890	—26.00	0.9433
1 a	133.10	1.4905	—23.60	0.9410
Extra	154.70	1.4900	—17.50	0.9525
2	61.30	1.5040	—51.40	0.9127
1 a	132.00	1.4900	—21.72	0.9349
1 a	143.00	1.4840	—16.75	0.9417

In our classification we have placed the most emphasis on the ester number as the determining factor, but have been influenced by the other constants.

Doctor Jahrling, of Santos and Jahrling, has very kindly furnished us with a number of samples of oils from his laboratory. The constants of these oils have been determined by the Bureau of Science and are given in Table VII.

TABLE VII.—*Constants of oils submitted by Jahrling.*

Sample No.	Grade.	Ester number.	Index of refraction 30/D.	Specific rotation 30/D.	Specific gravity 30°/30°.	Soluble in alcohol of—
				°		*Per cent.*
1	Extra	201.7	1.4762	− 6.70	0.9478	80
2	1 a	128.7	1.4913	−39.50	0.9445	90
3	Extra	153.8	1.4900	−27.50	0.9504	80
4	1 a	130.3	1.4919	−40.63	0.9452	90
5	Extra	164.4	1.4860	−20.08	0.9564	80
6	Extra	172.7	1.4850	−21.76	0.9579	80
7	1 a	129.9	1.4937	−25.34	0.9472	90
8	1 a	130.0	1.4965	−38.73	0.9450	90
9	1a	124.2	1.4944	−45.95	0.9469	90
10	Extra	157.3	1.4870	−16.23	0.9612	80
11	1 a	122.0	1.4938	−41.83	0.9467	90
12	Extra	148.2	1.4842	−25.80	0.9493	80
13	1 a	122.0	1.4913	−38.73	0.9435	90
14	Extra	157.3	1.4860	−14.12	0.9489	80

Of the 14 oils reported in Table VI, which are representative of the oils received by the Bureau of Science for examination, 11 have ester numbers higher than 120, Schimmel & Co.'s maximum; 9 have indices of refraction less than 1.4910, their minimum index of refraction; while all but two have specific rotation less than the minimum given by this firm.

The oils listed in Table VII show a similar superiority and justify an extension of Bacon's table. All 14 have ester numbers greater than 120, 7 have indices of refraction less than 1.4910, and 8 have specific rotation with a greater negative rotation than —37°.

The average of the constants for the year 1914, from January 1 to July 1, shows this same superiority in all the constants tabulated.

After due consideration of all the above-mentioned facts I believe Jahrling is justified in announcing an extension of the table of constants, as given in Table IV, and that these constants should be adopted as standard for classification.

SUMMARY

The exports in ylang-ylang for the last five years are given.

An extension of the classification at present in use is proposed. This extension is warranted on account of the large number of superior-grade oils produced.

One new test—solubility in alcohol—has been added as a confirmatory test.

PHILIPPINE OIL-BEARING SEEDS AND THEIR PROPERTIES: II[1]

By HARVEY C. BRILL and FRANCISCO AGCAOILI

(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

TWO TEXT FIGURES

The vegetable-oil industry is going through a transition period. Manufacturers and consumers are turning their attention to vegetable oils, and the processes of extraction, expression, refining, and deodorizing have been so greatly improved that these oils have invaded the domain of the animal fats and in many cases entirely usurped their place. In the warmer climates very strong prejudices are held by the Caucasians against the use of animal fats for edible purposes, because of a belief that they are deleterious to the health. This belief is spreading to the native peoples, and the holding of this belief, together with the limited available amount of animal fat, will result in a still more increased demand for edible vegetable oils. The increased demand will be accompanied by a further rise in price, unless larger quantities are available. This gradual rise in cost is illustrated by the table of prices of edible cottonseed oil and edible peanut oil taken from the figures published by a Hamburg importer and quoted by E. W. Thompson.[2]

TABLE I.—*Maximum and minimum prices of cottonseed and peanut oils.*

[Figures give cents per pound.]

	1904	1906	1908	1909	1910	1911	1912
Edible cottonseed oil:							
Lowest	5.06	5.78	6.43	6.27	6.27	7.00	6.93
Highest	6.05	6.60	7.92	8.91	9.24	8.03	8.36
Mean	5.55	6.19	7.17	7.59	7.75	7.51	7.64
Edible peanut oil:							
Lowest	--------	--------	8.80	9.02	9.79	9.57	10.34
Highest	--------	--------	9.02	9.68	10.50	10.78	10.56
Mean	--------	--------	8.91	9.35	10.14	10.17	10.45
Mean difference	--------	--------	1.74	1.76	2.39	2.66	2.81

[1] Received for publication March 19, 1915.

[2] *Dept. of Commerce, Special Agents Series No. 89.* Part II. Edible oils (1914), 18.

The price of each commodity has generally risen. The mean difference in price has likewise shown a gradual increase. This will result in a greater demand for the less favorably known cottonseed oil. But here the supply is not unlimited. To cite but one instance: Egyptian cotton is suffering severely from the attacks of the pink bollworm that is not only destroying the lint cotton, but is infesting the seed that reaches maturity and goes to the mill as well.

The awakened demand for edible vegetable oils has been accompanied by the withdrawal from the soap industry of such oils as can be made edible by refining, deodorizing, or hydrogenating. Thus many oils formerly used largely or exclusively for the manufacture of soap have now been shifted to this new industry by means of improved treatment in handling, and the soap manufacturers are either unable to obtain them at all or only at greatly inflated prices. To illustrate: Marseilles, which is the most important soap-manufacturing city in Europe, requires annually something like 120,000 tons of fat for this industry. Heretofore 40 per cent of this has been coconut oil. But in recent years, out of the total annual production of 85,000 tons of copra oil in Marseilles, about 50,000 tons are sold direct as an edible fat, and 10,000 tons are exported to the Netherlands and elsewhere for mixing with cottonseed oil, peanut oil, and other soft fats to make oleomargarin; this leaves but 25,000 tons for the soap trade there, when the normal supply from this source has been 48,000 tons.

Linseed oil the last two years has helped somewhat to alleviate this condition. It is easily hardened by hydrogenation, thus making it available for soap stock. And because of the record crop of 1913, when there were 2,700,000 metric tons, or half a million more than the year before, it has been sold at an extremely low price. The cost in Liverpool in April, 1914, was 5.4 cents per pound, or 2 cents cheaper than average tallow. However, the supply of linseed varies from year to year, and the soap industry dares not be entirely dependent on it for its supply of soap stock; consequently any new oil-bearing seeds are eagerly welcomed by importers and manufacturers in the hope that by their exploitation the present strain may be relieved and the price adjusted to the level held before the existing conditions arose.

A preliminary paper on Philippine oil-bearing seeds was published by Richmond and Rosario in 1907.[3] In this article they discussed the nuts known locally as lumbang bato (*Aleurites*

[3] *This Journal, Sec. A* (1907), 2, 439.

moluccana Willd.), lumbang banucalag (*Aleurites trisperma* Blanco), kapok [*Ceiba pentandra* (L.) Gaertn.] palo maria de la playa (*Calophyllum inophyllum* L.), physic nut (*Jatropha curcas* L.), and the castor-oil seed (*Ricinus communis* L.). The chemical properties and the principal local uses were given by the authors, along with a discussion of the future possibilities of the nuts. Since the publication of the above article, considerable data have been collected regarding some of these nuts and several new ones.

Chisochiton cumingianus (Harms).—This plant is placed in the natural family Melliaceae, the family to which santol belongs. It is of wide distribution in the Philippines, extending from northern Luzon to southern Mindanao, and has been reported by some to be abundant.

The native names recorded are as follows: In Benguet–Union, *batuakan* (Igorot); in Laguna, *balucanag, kalimotani, salaguin;* in Camarines, *balucanag;* in Cagayan, *papalsa, macalsa* (Negrito), and *marambalo* (Cagayan); in Bataan, *cato* (Tagalog); in Albay, *dudos* (Bicol); in Bukidnon, *valita;* in Negros, *malacalad* (Visayan). The use of the name "balucanag" by the natives of Camarines and Laguna would indicate that they recognized the seeds as oil producers, for "balucanag" is properly the name of the oil-producing *Aleurites trisperma* Blanco to which species, however, *Chisochiton cumingianus* has no other point of resemblance.

We have adopted the Tagalog name "cato" to designate this nut and shall refer to it hereafter as the cato nut. The fresh nut is half ellipsoid in shape, averaging 3 centimeters in length and 2.5 centimeters at the widest portion, with a rather hard shell constituting about 60 per cent of the total weight. This shell is somewhat difficult to separate from the meat.

One kilogram of shelled nuts after drying weighed 698 grams and yielded by extraction with petroleum ether 308 grams, or approximately 31 per cent of the whole nut, of a reddish brown oil with a specific gravity of 0.9203 at 15°.5 C. The composition of the dried kernels is given in Table II.

TABLE II.—*Composition of dry cato kernels.*

	Per cent.
Fat (by extraction)	44.12
Protein (N×6.25)	9.00
Ash	3.19

By expression the dry kernel gave 35.56 per cent oil. The oil has a rancid odor, is nondrying, and has purgative properties.

We are indebted to Prof. A. G. DuMez, director of the School of Pharmacy of the University of the Philippines, and Doctor de la Paz, of the University of the Philippines, for the examination of its physiological properties. They report:

Administered to cats in doses of 0.34 cubic centimeter per 500 grams body weight the effect was very slight, apparently causing a movement of the bowels within eight hours in 2 cases out of the 5 tried; when given in larger doses, 1.70 cubic centimeters per 500 grams body weight, the 3 cats treated were all affected within twelve hours of the administration of the dose, and the first movement was followed by successive movements within the twenty-four hours; doses of 3.34 cubic centimeters of cato oil for 500 grams body weight caused vomiting in both cases within the three hours following the administration of the dose.

The laxative effect of cato is weaker, however, than that of castor oil, 5 parts of cato oil being approximately equivalent to 1 part of castor oil. Its soap-making qualities were tested by the Bureau of Science with gratifying results, and it is now being used by at least one firm in Manila in this industry.

The chemical constants are given in Table III.

TABLE III.—*Chemical constants of cato oil.*

Specific gravity at 15° C.		0.9203
Specific gravity at 30° C.		0.9188
Butyro refractometer (reading at 30° C.)		60–61
Iodine value (Hanus)		80.78
Reichert-Meissl value		7.34
Saponification number		192.02
Free fatty acids (oleic)	per cent	3.98
Acid value	cc. N/10 KOH	7.06

Sterculia fœtida L.—*Sterculia* is a genus of the Sterculiaceae—the cacao or calumpang family—and is represented by many species in the tropics of both hemispheres. *Sterculia fœtida* occurs in eastern Africa to India, through Malaya to northern Australasia, and throughout the Philippines. It is known locally as calumpang (Tagalog, Pampanga); *bangar* (Ilocano); and *bobog* (Visayan). The follicles are large and woody, about 10 centimeters long, and contain from 10 to 15 seeds. The shells constitute approximately 48 per cent of the whole seed. The name calumpang is used to designate it throughout this paper.

The seeds are edible, but are slightly purgative when eaten in quantities. The composition of dried seeds examined by the Bureau of Science is given in Table IV.

TABLE IV.—*Calumpang dry shelled seeds.*

	Analysis by—	
	Bureau of Science.	Bolton and Jesson.[a]
	Per cent.	*Per cent.*
Fat (by extraction of dry seeds)	51.78	52.0
Protein (N×6.25)	21.61	
Starch	12.10	
Sugars	5.00	
Cellulose etc. (by difference)	5.51	
Ash	3.90	

[a] *Analyst* (1915), 40, 3.

The chemical constants of the oil are as follows:

TABLE V.—*Chemical constants of calumpang oil.*

	Analysis by—	
	Bureau of Science.	Bolton and Jesson.
Specific gravity at 30° C	0.9254	
Butyro refractometer reading at 40° C	63–64	59.8
Iodine value (Hanus)	76.04	75.8
Reichert-Meissl value	2.10	
Saponification number	212.01	193.7
Free fatty acids (oleic) per cent	0.45	1.0
Acid value cc. N/10 KOH	0.30	

The oil is a bland, sweet oil with a comparatively high melting point and is light yellow in color. Prof. A. G. DuMez has examined the oil for its physiological properties. He states:

The oil appears to resemble olive oil very much in its physiological action. Administered to dogs in doses of 1.5 to 3 cubic centimeters per kilogram body weight, it acts as a mild laxative. It is nontoxic and has no irritating action. It can be used in the same manner as olive oil and should be especially useful for culinary purposes.

Canarium pachyphyllum Perk.—The genus *Canarium* is widely distributed in the Philippine Islands and is represented by many species. The pili nut of commerce comes from some of these. The Tagalog name is *pagsainguin.* Two varieties of nuts from *Canarium pachyphyllum* were examined by us, the long and the short variety. Their description is given in Table VI:

TABLE VI.—*Description of two varieties of pili nuts.*

	Long.	Short.	*Canarium luzonicum.*[a]
Length ... cm	6 - 6.75	4.5 - 5	[b]4.5-6
Greatest width of triangular cross section ... do	2.25 - 2.5	2.25 - 2.5	2
Average weight of nuts ... grams	8.67	9.44	9.30
Shell ... per cent	81.13	81.71	
Kernel ... do	18.87	18.29	
Fat ... do	14.03	13.27	

[a] Bolton and Jesson, loc. cit.
[b] The nuts described here are doubtless from *Canarium pachyphyllum* and not *Canarium luzonicum*. The nuts of the latter are much smaller and are not available in any quantity.

The composition of the kernels is given in Table VII.

TABLE VII.—*Composition of the kernels of pili nuts.*

	Long.	Short.	*Canarium luzonicum.*[a]
	Per cent.	*Per cent.*	
Moisture	2.79	2.90	
Fat	74.39	72.53	72.20
Protein (N × 6.25)	12.06	11.88	
Sucrose	0.88	0.66	
Reducing sugars	0.45	1.35	
Starch (by difference)	4.33	5.11	
Crude fiber	2.15	2.42	
Ash	2.97	3.15	

[a] Bolton and Jesson, loc. cit.

The oil is bland, sweet, and suitable for salad and other culinary purposes; however, two objectionable features prevent its becoming an important article of commerce: namely, the high percentage and hardness of the shell. Table VIII gives the constants found for the pure dry oil.

TABLE VIII.—*Chemical constants of pili oil.*

	Long.	Short.	*Canarium luzonicum.*[a]
Specific gravity at 30° C	0.9067	0.9067	
Butyro refractometer reading at 30° C	54-54.2	54-54.2	[b]48.6
Iodine value (Hanus)	61.25	59.61	57.10
Reichert-Meissl value	3.3	2.2	
Saponification number	192.6	186.8	197.0
Free fatty acids (oleic) ... per cent	7.62	8.84	1.44
Acid value ... cc. N/10 NaOH	2.70	3.13	

[a] Bolton and Jesson, loc. cit. [b] At 40° C.

EXAMINATION OF THE DRYING PROPERTIES OF VARIOUS PHILIPPINE OILS

Richmond and Rosario[4] had planned to examine the oils of the Philippines for their drying qualities, but for various reasons were unable to do so. A great deal of interest is shown in drying oils by manufacturers, because of the wide and varied uses to which such oils are put. On this account we have made a rather extensive examination of the drying qualities of these oils and a critical study of some special tests for their distinction.

TABLE IX.—*Solubility of Philippine vegetable oils in alcohol and ether.*

Botanical name.	Local name.	Solubility of oil in—		
		Absolute alcohol.	90 per cent alcohol.	Ethyl ether.
Sterculia fœtida	Calumpang	Insoluble (1-4)	Insoluble	Not so readily.
Chisochiton cumingianus.	Cato	Soluble (1-1)	do	Easily.
Aleurites moluccana	Lumbang bato	Insoluble (1-4)	do	Do.
Aleurites trisperma	Lumbang banucalag.	Soluble (1-1)	do	Do.
Ceiba pentandra	Kapok	Insoluble (1-4)	do	Do.
Canarium pachyphyllum.	Pili	do	do	Do.
Calophyllum inophyllum.	Palo maria de la playa.	Soluble (1-1)	do	Do.
Calophyllum wallichianum.	Palo maria del monte.	do	do	Do.

This scheme would make it possible to distinguish lumbang bato from lumbang banucalag, since the former is insoluble in absolute alcohol in the proportion of 1 to 4, while the latter is soluble in the proportion of 1 to 1.

Aleurites moluccana and Aleurites trisperma.—These oils, known locally as lumbang bato and lumbang banucalag, respectively, have been discussed by Richmond and Rosario.[5]

A good deal of contradictory information has been recorded in the literature in regard to the properties of the press cake. Drury, Useful Plants, has this statement:

> The cake, after expression of the oil, is a good food for cattle, and useful as manure.

The United States Dispensatory states:

> The cake left after the expression of the oil, given to a dog in the dose of about half an ounce produced no vomiting, but acted strongly as a purgative.

[4] Loc. cit. [5] Loc. cit.

TABLE X.—*Reactions of Philippine vegetable oils with nitric and sulphuric acids.*

Local name.	Nitric acid.	Sulphuric acid.	Mixture of nitric and sulphuric acids.
Calumpang	Golden yellow; limpid	Dark red; thickens	Yellow-brown; thickens.
Cato	Yellow-brown; limpid	Brownish red; thickens somewhat	Almost black; thickens somewhat.
Lumbang bato	Cherry-colored; limpid	Red-brown; viscous	Cherry brown; limpid.
Lumbang banucalag	Yellow-brown; viscous	Red-brown; semiviscous	Brown (darker than above); viscous.
Kapok	Light yellow; limpid	Dark yellowish red; almost solid	Deep red; limpid.
Pili	Golden yellow; limpid	Brownish red; thickens somewhat	Same as with nitric acid.
Palo maria de la playa	Orange; limpid	Red; thickens somewhat	Brown; thickens slightly.
Palo maria del monte	Reddish yellow; limpid	Darker than above; semiviscous	Yellowish brown; limpid.

The Agricultural Gazette of New South Wales [6] claims that the press cake is poisonous to cattle. Mr. D. S. K. Pahu, a native of the Hawaiian Islands, employed in the Executive Bureau of the Insular Government here, informed us that the lumbang nut, known in the Hawaiian Islands as the kukui nut, is considered a delicacy when roasted and is eaten without deleterious results in this condition, but that when eaten in the fresh state it has strong physiological properties, causing nausea and dizziness. Guthrie and Ramsay [7] announce:

> It is a drying oil and is used in the arts for the same purposes as linseed oil, and for burning. * * * It is used medicinally as a plaster and as an article for diet—as olive oil is used.

On the other hand, the Chinese, who are the greatest dealers in this commodity in Manila, affirm that the oil cannot be used for culinary purposes on account of its causing dizziness and nausea. We have tested the heated press cake and the extracted press cake by feeding chickens with each for intervals of ten days with no harmful results to the fowls.

Most of this oil is expressed by the Chinese by means of crude, wooden hand presses, having a capacity of about 800 grams. One small factory can express about 75 liters of oil per day; but as less than 20 per cent of the total oil is extracted, much is going to waste. At present it sells at approximately 12 centavos (6 cents United States currency) per pound in Manila.

In 1911 the United States imported 5,000,000 gallons of Chinese wood oil from China. This oil is used extensively for special varnishes and linoleum and for other similar purposes. This oil is so highly appreciated by the United States paint concerns that 40,000 trees have been planted in the Southern States. These are expected to furnish from one fourth to one third of the present supply of tung oil in the United States when they reach maturity.[8] We believe either of the lumbang oils could be substituted for tung oil, as they are quick-drying, giving a clear, transparent, nonsticky film on a surface when exposed to the air for a short time. Thrum [9] says:

> The last use, to our knowledge, made of it in house painting here was at the construction of the Judd building about 1855, by R. Gilliland, who is said to have made the statement that it was good for fifteen to twenty years.

[6] *Agr. Gaz. N. S. W.* (1906), 17, 859.
[7] Ibid. (1906), 17, 859.
[8] *Drugs, Oils and Paints* (1914), 30, 207.
[9] *Hawaiian Annual* (1893), 107.

The following statement occurs in the Bulletin of the Imperial Institute,[10] London:

> Kukui (Lumbang bato) oil belongs to the drying oils typified by linseed—suitable for soap, oil-varnishes, paints, linoleum, and other similar purposes.

Lumbang banucalag oil, allowed to stand at room temperature in an extraction flask exposed to the air for some time, became viscous and later settled to a clear straw-yellow gum, which was insoluble in alcohol and kerosene, but soluble in turpentine and alcoholic potash. The turpentine solution dried to a thin transparent film when exposed on a glass plate in the course of a few hours.

Lumbang banucalag, lumbang bato, and cato oils were placed in small flasks on the steam bath, and dry air was passed through them. The flasks were weighed at intervals, and the change in weight was determined. This percentage change, marked — where a loss was found and + where the oil gained in weight, is recorded in Table XI.

TABLE XI.—*Change in weight of lumbang and cato oils when blown at a temperature of 100° C.*

Serial No.	Time.	Lumbang banucalag.	Lumbang bato.	Cato.
	Hours.	*Per cent.*	*Per cent.*	*Per cent.*
1	1	−3.80	−4.66	−0.32
2	2	−3.98	−4.85	−0.38
3	3	−3.99	−4.98	−0.38
4	4	−4.01	−5.02	−0.35
5	5	−3.95	−5.03	−0.32
6	6.5	−3.86	−4.81	−0.06
7	9.5	−3.79	−4.26	−0.05
8	12.5	−3.62	−3.96	+0.01
9	16.5	−3.51	−3.38	+0.21
10	21	−2.81	2.30	+0.45
11	22.5	−2.70	−2.29	+0.47
12	28.5	−1.75	−1.89	+0.48
13	31	−1.25	−1.54	+0.50
14	34	−0.93	−1.30	+0.51
15	36	−0.64	−1.00	+0.52

The lumbang oils show a maximum loss in weight at the end of the fourth hour; thereafter the weight increases steadily.

[10] *Bull. Imp. Inst.*, London (1907), 5, 136.

At the end of the experiment both had become thick and gummy with none of the original oily appearance, while cato oil, on the other hand, showed very little change in its weight and practically no difference in its physical properties when treated thus. The above oils were heated to 270° C. and held there for fifteen minutes. The sample of lumbang bato used suffered a loss of 1.5 per cent in weight, but showed no deposit of foots on cooling; lumbang banucalag lost 0.8 per cent and showed a slight deposit of foots; cato oil lost 1.6 per cent of its original weight and deposited a small amount of foots when allowed to stand. All three darkened somewhat. Seventy-five hundredths per cent precipitated lead and 0.75 per cent manganese borate were added to each, and they were then heated on the water bath for three hours. Only a part of the dryer went into solution, but the effect on the lumbang oils was decidedly marked. When the "boiled" oils were spread evenly on glass plates and placed in a horizontal position in a box protected from dust in subdued light at room temperature, lumbang banucalag oil dried to a clear film in five hours, while lumbang bato oil underwent a like change in six hours. Cato oil did not dry and at the end of twenty days remained wet and without having undergone any noticeable change in consistency. These experiments demonstrate that the lumbang oils are drying oils of good quality and capable of taking a dryer; cato oil, on the other hand, shows no improvement when treated thus.

Further drying tests were arranged for the native oils under conditions approximating those existing when the oil is used for painting purposes, to determine the rate of drying and the change in weight. These changes are demonstrated in figs. 1 and 2. The oils were spread evenly on glass plates 7.5 by 4 inches in size, previously weighed and again weighed when covered with the oil film. They were then placed in a horizontal position on racks in boxes, the sides of which were made of a good quality of cheese cloth. This prevented the entrance of dust, insects, etc., but allowed a free passage of air. They were weighed each morning. Duplicates were run in all cases, and the average result is plotted. In figs. 1 and 2 the time in days is plotted along the horizontal axis and the per cent increase along the vertical axis.

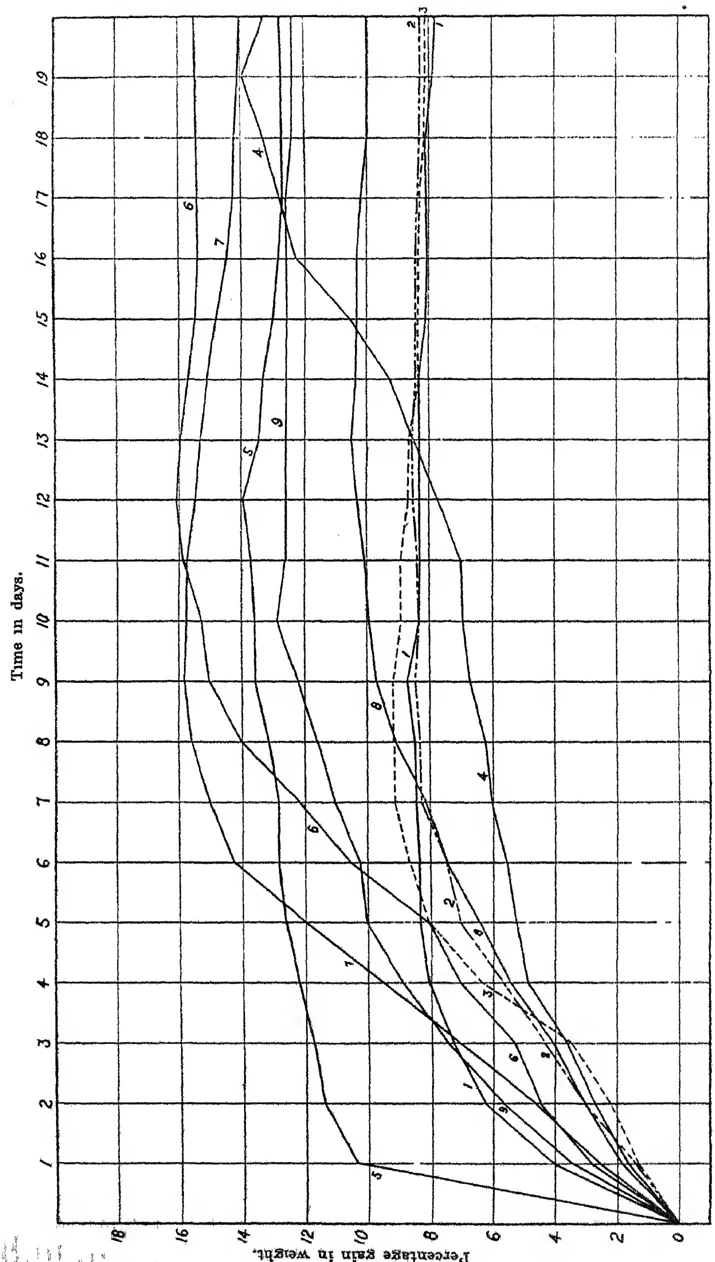


FIG. 1. For description of the curves see Table XII.

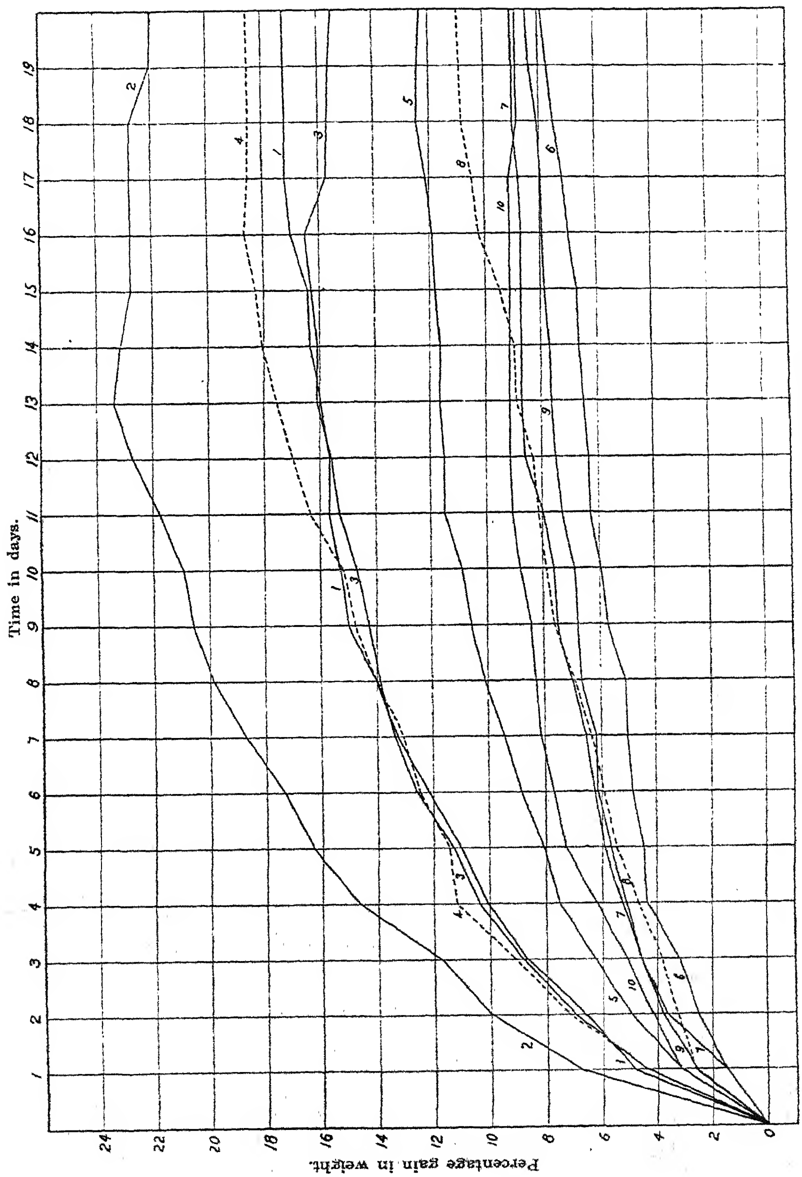


FIG. 2. For description of the curves see Table XIII.

TABLE XII.—*Description of oils of fig. 1.*

Curve.	Oil.	Condition.	Day when crest is reached.	Maximum increase in weight.	Day when maximum is reached.	Day when film is dry.	Condition of film at end of 20 days.
				Per ct.			
1	Lumbang bato	Bottled 2 years; heated for 3 hours at 100° C. before use.	4- 5	8.76	9	6	Clear, firm.
2	Lumbang banucalag.	do	6- 7	8.59	11	5	Do.
3	do	Bottled 2 years	6- 7	9.18	9	5	Do.
4	do	Freshly expressed	16-19	13.98	19	13	Clear, slight tackiness.
5	Linseed, "boiled"	Commercial sample.	1- 4	13.96	12	4	Clear, firm.
6	Lumbang bato	Freshly expressed	9-12	16.09	12	8	Do.
7	do	Bottled 2 years	6- 9	15.91	9	7	Do.
8	do	Bottled 2 years; heated for 15 minutes at 270° C. before use.	7- 9	10.50	13	6	Do.
9	Lumbang banucalag.	do	8-10	12.90	10	5	Slight cloudiness, firm.

TABLE XIII.—*Description of oils of fig. 2.*

Curve.	Oil.	Condition.	Day when crest is reached.	Maximum increase in weight.	Day when maximum is reached.	Condition of film at end of 20 days.
				P. ct.		
1	Pili	Freshly extracted; heated for 3 hours at 100° C. before use.	10	17.22	17	Slightly thickened, not dry.
2	Cato	Freshly extracted	13	23.42	13	Do.
3	do	Freshly extracted; heated for 3 hours at 100° C. before use.	13	16.52	16	Slightly thicker than 2.
4	Palo maria de la playa.	Bottled 2 years	14	18.66	16	No appreciable change.
5	Palo maria del monte.	do	11	12.46	18	Do.
6	Palo maria de la playa	Bottled 2 years, heated for 3 hours at 100° C. before use.	11	7.86	20	Do.
7	Palo maria del monte.	do	12	9 00	18	Do
8	Calumpang	Freshly extracted	16	10.91	19	Slightly thickened.
9	Kapok	Bottled 2 years; heated for 3 hours at 100° C. before use.	8	8.46	20	Considerably thickened.
10	Cato	Freshly extracted; heated at 270° C. for 15 minutes before use.	7	9.18	12	Do.

Redman, Weight, and Block [11] have determined the drying rates of linseed, china wood, fish, and soya bean oils. Raw linseed oil reached a maximum increase in weight of 11.7 per cent at the end of the sixth day; china wood oil shows an increase of 10.5 per cent between the eighth and ninth days; the fish oils show an increase of 13 per cent between the third and fourth days; while soya bean oils show an increase of 7.7 per cent between the sixth and seventh. (Compare with the results as recorded in Table XII). Lippert [12] gives the increase for raw linseed oil as 12.4 per cent on drying. Meister [13] says that china wood oil is slower in absorbing oxygen than linseed oil, and although the film forms in from one to two days it does not become firm until the fifth or sixth. The lumbang oils compare very favorably with china wood oil and linseed oil in rate of drying, quality of film, and the per cent change in weight when drying. The results of these investigators are especially interesting in comparison with the results obtained by us as set forth in Tables XII and XIII.

SUMMARY

The percentage yields, chemical constants, physiological properties, and commercial possibilities of cato, calumpang, and pili nut oils have been given and discussed.

An investigation of the drying qualities of the oils from the nuts of calumpang, cato, lumbang bato, lumbang banucalag, kapok, pili, palo maria de la playa, and palo maria del monte is recorded, demonstrating that lumbang bato and lumbang banucalag are drying oils of high quality, comparing favorably with linseed and china wood oils, and that the others have no appreciable drying qualities.

[11] *Journ. Ind. & Eng. Chem.* (1913), 5, 630.
[12] *Journ. Franklin Inst.* (1899), 156.
[13] *Journ. Soc. Chem. Ind.* (1911), 30, 95.

ILLUSTRATIONS

TEXT FIGURES

THE ENZYMES OF CACAO [1]

By Harvey C. Brill

(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

The necessity for fermenting or sweating cacao is now generally acknowledged. The principal changes brought about by this process are: (1) The removal of the greater portion of the sugary pulp or parenchymatous tissue surrounding the beans, (2) the dissociation of the bean from its testa or seed coat, (3) the promotion of chemical changes within the seeds, (4) the conversion of the bitter astringent taste into a palatable sweet one, and (5) an improvement in color, break, and flavor.

Investigators are not agreed as to the cause of these changes and attribute them to the action of various agencies. Hart [2] contends that the process of—

> fermentation or sweating in cacao consists in an alcoholic fermentation of the sugars in the pulp of the fruit accompanied by a loss of some of the albuminoid and indeterminate nitrogenous constituents of the beans. * * * Some parts of the carbohydrates other than sugars undergo hydrolysis and either escape in the runnings from the boxes in the form of glucose, or undergo in turn the alcoholic and acetic fermentations. During this change some of the astringent matters to which the somewhat acrid taste of the raw beans is due are also hydrolised, and thus a marked improvement in flavour is gained.

Harrison [3] holds the same view.

A. Schulte im Hofe,[4] in an investigation carried out at Victoria in Cameroon, came to the conclusion that the changes brought about in the cacao bean during fermentation were the result of an oxidation process and were precisely similar to those taking place during the conversion of green tea into black tea. He made no attempt to determine if the oxidation was due to the action of enzymes or arose from other causes.

[1] Received for publication February 26, 1915.

[2] Cacao. Trinidad, 2d ed. (1900), 106–107.

[3] *Proc. Agr. Soc. Trinidad* (1896–97), 2, 250.

[4] Die Kultur und Fabrication von Tee in Britisch Indien und Ceylon mit Rücksicht auf den wirtschaftlichen Wert der Teekultur für die deutschen Kolonien. *Tropenpflanzer* (1901), 5 (2), 37.

That the fermentation is the result of biological action is the conclusion of J. Sack.[5]

Preyer[6] has isolated a yeast, *Saccharomyces theobromæ*, from fermenting cacao and has recommended the use of the pure culture of this for the initiation of the fermentation. Besides the above he observed *S. cerevisiæ*, *S. ellipsoidies*, and *S. membranaefaciens* in fermenting cacao. Others have noted the presence of *Penicillium* and *S. apiculatus*.

However, not much success has been attained with the use of pure cultures of yeasts, and not much development can be looked for along this line, since the use of a pure strain of yeast would necessitate the sterilization of the culture medium, the cacao. Sterilization would destroy the enzymes present. Behrens[7] has pointed out that the changes desired from fermentation do not occur when the enzymes are destroyed.

That the color change in the bean from white or violet to brown is only indirectly produced by fermentation is maintained by Loew.[8] He insists that the brown coloration is due to the action of the oxidases or oxidizing enzymes, since this same brown coloration is produced when the beans are crushed and exposed to the air. These oxidases are stored up in the protoplasm of the bean of the cell and are liberated when the cells are killed, without injury to the enzyme. The enzyme then becomes active.

It is a very generally accepted belief that enzymes are an important factor in the changes tobacco undergoes during the curing process. With this in mind Oosthuizen and Shedd[9] have investigated the enzymes of the tobacco plant.

Many plants and plant products[10] are being investigated to discover the enzymes present and thus throw some light on the changes they undergo when ripening and germinating and their influence on the system when used for foods.

On account of the great interest manifested in enzymology and in the hope that some light may be thrown on the cause of the changes taking place in the fermentation of cacao and on the real nature of the changes themselves, this investigation has been undertaken.

[5] H. H. Smith, The Fermentation of Cacao. John Bale Sons and Danielsson, London (1913), 138–141.

[6] *Tropenpflanzer* (1901), 5, 151.

[7] Lafar, Handbuch der technischen Mykologie, 1, 655.

[8] *Porto Rico Exp. Sta. Rep.* (1907).

[9] *Journ. Am. Chem. Soc.* (1913), 35, 1289.

[10] Chelpin, General Chemistry of the Enzymes. Trans by Pope. John Wiley & Sons (1912).

EXPERIMENTAL

A 10 per cent aqueous solution of the pulp and seed of cacao was made by grinding them in a mortar with clean sand under water, allowing them to stand two hours, and afterwards filtering through cheese cloth. The seed was freed from the pulp and surrounding slime by very careful washing in running water and later removal of the inclosing membrane. Three series of experiments were run: namely, with the surrounding pulp, the fresh clean seed, and the clean fermented seed. The last was prepared by placing the seed in the incubator and allowing the process of fermentation to proceed for four days. It was then removed, very carefully separated from the outer slime and surrounding membrane, and treated as the other two. In all cases toluene was used as the antiseptic.

Tests were then carried out with these solutions for the detection of enzymes.

TABLE I.—*Tests for lipase.*

SERIES 1.

	Cc. N/10 NaOH.
15 cc. water, 10 cc. pulp extract, 48 hours at 38° C	0.40
15 cc. water, 10 cc. pulp extract, 1 cc. olive oil, 48 hours at 38° C	0.45
15 cc. water, 10 cc. pulp extract heated, 1 cc. olive oil, 48 hours at 38° C	0.42
25 cc. water, 1 cc. olive oil, 48 hours at 38° C	0.45

SERIES 2.

16 cc. water, 10 cc. seed extract, 48 hours at 38° C	0.40
15 cc. water, 10 cc. seed extract, 1 cc. olive oil, 48 hours at 38° C	0.40
15 cc. water, 10 cc. seed extract heated, 1 cc. olive oil, 48 hours at 38° C	0.45

SERIES 3.

10 cc. water, 10 cc. fermented seed extract, 48 hours at 38° C	0.72
15 cc. water, 10 cc. fermented seed extract, 1 cc. olive oil, 48 hours at 38° C	0.72
15 cc. water, 10 cc. fermented seed extract heated, 1 cc. olive oil, 48 hours at 38° C	0.78

No lipase was present that reacted on olive oil, as the control required the same amount of N/10 NaOH for neutralization as the active sample. Duplicates of the above were carried out substituting ethyl butyrate for olive oil with the like negative results.

TABLE II.—*Tests for emulsin.*

SERIES 1.

	Test for—		
	Glucose.	Hydrocyanic acid.	Benzaldehyde.
10 cc. water, 10 cc. pulp extract, 48 hours at 38° C	[a] ++	−	−
10 cc. amygdalin solution, 10 cc. pulp extract, 48 hours at 38° C	++	−	−
10 cc amygdalin solution, 10 cc. pulp extract heated, 48° C	++	−	−
10 cc. amygdalin solution, 10 cc. pulp water, 48 hours at 38° C	−	−	−

SERIES 2.

10 cc. water, 10 cc. seed extract, 48 hours at 38° C	−	−	−
10 cc. amygdalin solution, 10 cc. seed extract, 48 hours at 38° C	−	−	−
10 cc. amygdalin solution, 10 cc. seed extract heated, 48 hours at 38 °C	−	−	−

SERIES 3.

10 cc. water, 10 cc. fermented seed extract, 70 hours at 38° C	−	−	−
10 cc. amygdalin solution, 10 cc. fermented seed extract, 70 hours at 38° C	−	−	−
10 cc. amygdalin solution, 10 cc. fermented seed extract heated, 70 hours at 38° C	−	−	−

[a] + means slight test, ++ means fair test, +++ means good test, ++++ means strong test, wherever used in this paper.

The amygdalin solution was a 10 per cent solution in water. The results of the tests for emulsin with amygdalin were in all cases negative. A test for glucose was obtained in series 1, but this positive test was due to the presence of invert sugar in the original pulp. The tests for hydrocyanic acid and benzaldehyde were negative in all cases. This is different from the results obtained by J. Sack,[11] who claims to have obtained a splitting of amygdalin by the enzymes in cacao.

TABLE III—*Tests for cascase.*

SERIES 1

	Cc N/10 NaOH	Tryptophane reaction
20 cc. water, 10 cc. pulp extract, 48 hours at 38° C	0.05	−
20 cc. casein solution, 10 cc pulp extract, 48 hours at 38° C	1 60	
20 cc. casein solution, 10 cc. pulp extract heated, 48 hours at 38° C	0.35	−
20 cc. casein solution, 10 cc. water, 48 hours at 38° C	0 35	−

[11] H. H. Smith, The Fermentation of Cacao, 148.

TABLE III.—*Tests for casease*—Continued.

SERIES 2.

	Cc. N/10 NaOH.	Tryptophane reaction.
20 cc. water, 10 cc. seed extract, 48 hours at 38° C	0.05	—
20 cc. casein solution, 10 cc. seed extract, 48 hours at 38° C	0.75	+
20 cc. casein solution, 10 cc. seed extract heated, 48 hours at 38° C	0.25	—

SERIES 3.

	Cc. N/10 NaOH.	Tryptophane reaction.
20 cc. water, 10 cc. fermented seed extract, 70 hours at 38° C	0.05	—
20 cc. casein solution, 10 cc. fermented seed extract, 70 hours at 38° C	1.05	
20 cc. casein solution, 10 cc. fermented seed extract heated, 70 hours at 38° C	0.65	—
20 cc. casein solution, 10 cc. water, 70 hours at 38° C	0.65	—

This 5 per cent casein solution was made by grinding casein under water, neutralizing with N/10 NaOH, making up to the mark, allowing it to stand overnight at a temperature of 38° C., and filtering.

The amino acids were titrated by the method of Sorensen.[12]

There is evidence of the presence of a proteolytic enzyme which hydrolyzes casein. This is more evident in series 1 and 3; but as the active sample in all cases required more NaOH for neutralization than was needed for the controls, the proof of the presence of a casease is fairly conclusively established.

TABLE IV.—*Tests for albuminase.*

SERIES 1.

	Cc. N/10.	Tryptophane test.
25 cc. water, 10 cc. pulp extract, 72 hours at 38° C	0.05	—
25 cc. egg albumin solution, 10 cc. pulp extract, 71 hours at 38° C	0.75	[a] +
25 cc. egg albumin solution, 10 cc. pulp extract heated, 71 hours at 38° C	0.50	—
25 cc. egg albumin solution, 10 cc. water, 71 hours at 38° C	0.60	—

SERIES 2.

	Cc. N/10.	Tryptophane test.
25 cc. water, 10 cc. seed extract, 72 hours at 38° C	0.05	—
25 cc. egg albumin solution, 10 cc. seed extract, 72 hours at 38° C	0.55	—
25 cc. egg albumin solution, 10 cc. seed extract heated, 72 hours at 38° C	0.40	—

SERIES 3.

	Cc. N/10.	Tryptophane test.
25 cc. water, 10 cc. fermented seed extract, 75 hours at 38° C	0.05	—
25 cc. egg albumin solution, 10 cc. fermented seed extract, 75 hours at 38° C	1.20	—
25 cc. egg albumin solution, 10 cc. fermented seed extract heated, 75 hours at 38° C	0.95	—

[a] Very faint.

[12] *Biochem. Zeitg.* (1887–88), 7, 45.

Albuminases are probably absent in cacao or, at least, so feebly active as to be negligible in so far as their influence on the fermentation may be concerned.

TABLE V.—*Tests for protease.*

SERIES 1.

	Cc. N/10.	Tryptophane test.
20 cc. water, 10 cc. pulp extract, 48 hours at 38° C	0.05	—
20 cc. peptone solution, 10 cc. pulp extract, 48 hours at 38° C	2.20	+
20 cc. peptone solution, 10 cc. pulp extract heated, 48 hours at 38° C	1.20	—
20 cc. peptone solution, 10 cc. water, 48 hours at 38° C	1.05	—

SERIES 2.

20 cc. water, 10 cc. seed extract, 48 hours at 38° C	0.05	—
20 cc. peptone solution, 10 cc. seed extract, 48 hours at 38° C	1.10	—
20 cc. peptone solution, 10 cc. seed extract heated, 48 hours at 38° C	1.05	—

SERIES 3.

20 cc. water, 10 cc. fermented seed extract, 74 hours at 38° C	0.05	—
20 cc. peptone solution, 10 cc. fermented seed extract, 74 hours at 38° C	2.00	+
20 cc. peptone solution, 10 cc. fermented seed extract heated, 74 hours at 38° C	1.10	—

The peptone solution used was a 2 per cent solution of Witte peptone in water.

Judging from the tryptophane test and the difference in number of cubic centimeters of NaOH required for the neutralization of the active samples and the controls, the pulp and fermented seed extracts contain a proteolytic enzyme which reacts with peptone. It appears to be absent in the seed extract.

TABLE VI.—*Tests for inulase.*

SERIES 1.

	Test for glucose
11 cc. water, 10 cc. pulp extract, 70 hours at 38° C	++
10 cc. water, 10 cc. pulp extract, 1 cc. inulin solution, 70 hours at 38° C	++
10 cc. water, 10 cc. pulp extract heated, 1 cc. inulin solution, 70 hours at 38° C	++
20 cc. water, 1 cc. inulin solution, 70 hours at 38° C	—

SERIES 2.

11 cc. water, 10 cc. seed extract, 70 hours at 38° C	—
10 cc. water, 10 cc. seed extract, 1 cc. inulin solution, 70 hours at 38° C	—
10 cc. water, 10 cc. seed extract heated, 1 cc. inulin solution, 70 hours at 38° C	—

TABLE VI.—*Tests for inulase*—Continued.

SERIES 3.

	Test for glucose.
11 cc. water, 10 cc. fermented seed extract, 70 hours at 38° C	+
10 cc. water, 10 cc. fermented seed extract, 1 cc. inulin solution, 70 hours at 38° C	+
10 cc. water, 10 cc. fermented seed extract heated, 1 cc. inulin solution, 70 hours at 38° C	+

The inulin solution used was a 10 per cent solution in water.

The test for glucose carried out showed that no hydrolysis of inulin had taken place, thus proving the absence of inulase.

TABLE VII.—*Tests for reductase.*

SERIES 1.

	Color change.
10 cc. water, 10 cc. pulp extract, 1 cc. methylene blue solution, 24 hours at 38° C	++
10 cc. water, 10 cc. pulp extract heated, 1 cc. methylene blue solution, 24 hours at 38° C	++
20 cc. water, 1 cc. methylene blue solution, 24 hours at 38° C	—

SERIES 2.

10 cc. water, 10 cc. seed extract, 1 cc. methylene blue solution, 24 hours at 38° C	+++
10 cc. water, 10 cc. seed extract heated, 1 cc. methylene blue solution, 24 hours at 38° C	+++

SERIES 3.

10 cc. water, 10 cc. fermented seed extract, 1 cc. methylene blue solution, 24 hours at 38° C	+++
10 cc. water, 10 cc. fermented seed extract heated, 1 cc. methylene blue solution, 24 hours at 38° C	+++

The methylene blue solution was made by saturating 1 cubic centimeter of alcohol with methylene blue and diluting the resulting solution to 40 cubic centimeters with water. In each case the change in color for the control is the same as the change in the fresh sample, indicating that there is no reductase present.

TABLE VIII.—*Tests for oxidases.*

SERIES 1.

	Change in color noted at 38° C.			
	Initial.	End of— ½ hour.	4 hours.	24 hours.
20 cc. water, 1 cc. guaiacum tincture	—	—	—	—
10 cc. water, 10 cc. pulp extract, 1 cc. guaiacum tincture	+	++	+++	—
10 cc. water, 10 cc. pulp extract heated, 1 cc. guaiacum tincture	—	—	—	—

TABLE VIII.—*Tests for oxidases*—Continued.

SERIES 2.

	Change in color noted at 38° C.			
	Initial.	End of—		
		½ hour.	4 hours.	24 hours.
20 cc. water, 10 cc. seed extract, 1 cc. guaiacum tincture	++	+++	++++	+
20 cc. water, 10 cc. seed extract heated, 1 cc. guaiacum tincture	—	—	—	—

SERIES 3.

20 cc. water, 10 cc. fermented seed extract, 1 cc. guaiacum tincture	+	++	++	+
20 cc. water, 10 cc. fermented seed extract heated, 1 cc. guaiacum tincture	—	—	—	—

The 20 per cent guaiacum tincture used here was made by grinding the gum in alcohol and allowing it to stand at room temperature for two days. At the end of this time the solution was filtered and used at once.

Oxidases exist in the fresh seed in large quantities, but are present in relatively large quantities in the pulp also, although considerably less than in the seed. They exist in comparatively small amounts in the fermented seed, as evidenced by the changes in color recorded above. When the seeds are ground in water, the solution very soon assumes a brown color, and a flocculent precipitate separates out. This mass is the tannin precipitated by the oxidases.

TABLE IX.—*Tests for diastase.*

SERIES 1.

	Test for—	
	Glucose.	Starch.
40 cc. water, 10 cc. pulp extract, 48 hours at 38° C	++	—
40 cc. starch solution, 10 cc. pulp extract, 48 hours at 38° C	++	++++
40 cc. starch solution, 10 cc. pulp extract heated, 48 hours at 38° C	++	++++
40 cc. starch solution, 10 cc. water, 48 hours at 38° C	—	++++

SERIES 2.

40 cc. water, 10 cc. seed extract, 48 hours at 38° C	—	—
40 cc. starch solution, 10 cc. seed extract, 48 hours at 38° C	—	++++
40 cc. starch solution, 10 cc. seed extract heated, 48 hours at 38° C	—	++++

TABLE IX.—*Tests for diastase*—Continued.

SERIES 3.

	Test for—	
	Glucose.	Starch.
40 cc. water, 10 cc. fermented seed extract, 70 hours at 38° C	—	—
40 cc. starch solution, 10 cc. fermented seed extract, 70 hours at 38° C	++++	+
40 cc. starch solution, 10 cc. fermented seed extract heated, 70 hours at 38° C	—	++++

A 1 per cent solution of soluble starch was used in the examination for diastase. Fehling solution was used in the test for glucose and a 1 per cent solution of iodine in the test for starch. The test for diastase was negative in the pulp extract and the seed extract, but in the fermented seed extract the active sample gave a heavy test (++++) for glucose, while the control gave only a fair test (++), proving that considerable starch had been hydrolyzed by a diastase present. I conclude that diastase is present in the fermenting seed only.

TABLE X.—*Tests for invertase.*

SERIES 1.

	Test for invert sugar.
15 cc. water, 10 cc. pulp extract, 48 hours at 38° C	++
10 cc. water, 10 cc. pulp extract, 5 cc. sugar solution, 48 hours at 38° C	++++
10 cc. water, 10 cc. pulp extract heated, 5 cc. sugar solution, 48 hours at 38° C	++
20 cc. water, 5 cc. sugar solution, 48 hours at 38° C	—

SERIES 2.

15 cc. water, 10 cc. seed extract, 48 hours at 38° C	—
10 cc. water, 10 cc. seed extract, 5 cc. sugar solution, 48 hours at 38° C	—
10 cc. water, 10 cc. seed extract heated, 5 cc. sugar solution, 48 hours at 38° C	—

SERIES 3.

	Ventzke scale.
	°
15 cc. water, 10 cc. fermented seed extract, 73 hours at 38° C	+ 0.0
10 cc. water, 10 cc. fermented seed extract, 5 cc. sugar solution, 73 hours at 38° C	+ 5.4
10 cc. water, 10 cc. fermented seed extract heated, 5 cc. sugar solution, 73 hours at 38° C	+ 6.5
20 cc. water, 5 cc. sugar solution, 73 hours at 38° C	+ 6.8

A 10 per cent cane-sugar solution was used for the detection of invertase.

The test for invertase was strongly positive in the pulp extract; a fair test resulted in the fermented seed extract, while a negative test was obtained in the seed extract.

TABLE XI.—*Tests for raffinase.*

SERIES 1.

	Ventzke scale.
	°
10 cc. water, 10 cc. pulp extract, 72 hours at 38° C	+ 0.5
10 cc. raffinose solution, 10 cc. pulp extract, 72 hours at 38° C	+ 5.6
10 cc. raffinose solution, 10 cc. pulp extract heated, 72 hours at 38° C	+11.0
10 cc. raffinose solution, 10 cc. water, 72 hours at 38° C	+11.0

SERIES 2.

10 cc. water, 10 cc. seed extract, 72 hours at 38° C	0.0
10 cc. raffinose solution, 10 cc. seed extract, 72 hours at 38° C	+10.9
10 cc. raffinose solution, 10 cc. seed extract heated, 72 hours at 38° C	+11.5

SERIES 3.

10 cc. water, 10 cc. fermented seed extract, 74 hours at 38° C	0.0
10 cc. raffinose solution, 10 cc. fermented seed extract, 74 hours at 38° C	+ 9.8
10 cc. raffinose solution, 10 cc. fermented seed extract heated, 74 hours at 38° C	+11.3

A 5 per cent solution of raffinose was used in this experiment. Any hydrolysis of the raffinose by raffinase would decrease the polariscope reading. There is a considerable decrease of the reading for the fresh pulp extract from the reading of the controls used and a slight difference in the reading of the analogous solution in series 2 and 3, indicating the presence of considerable activity of the raffinase in series 1 and less activity in series 2 and 3; or, the pulp contains a raffinase in considerable quantities, the fermented seed in somewhat less quantities, while the fresh seed shows scarcely any activity toward raffinose.

TABLE XII.—*Tests for maltase.*

SERIES 1.

	Ventzke scale.
	°
10 cc. water, 10 cc. pulp extract, 72 hours at 38° C	+ 0.5
10 cc. maltose solution, 10 cc. pulp extract, 72 hours at 38° C	+23.4
10 cc. maltose solution, 10 cc. pulp extract heated, 72 hours at 38° C	+23.7
10 cc. maltose solution, 10 cc. water, 72 hours at 38° C	+23.4

TABLE XII.—*Tests for maltase*—Continued.

SERIES 2.

	Ventzke scale.
10 cc. water, 10 cc. seed extract, 72 hours at 38° C	0.0
10 cc. maltose solution, 10 cc. seed extract, 72 hours at 38° C	+23.5
10 cc. maltose solution, 10 cc. seed extract heated, 72 hours at 38° C	+24.0

SERIES 3.

10 cc. water, 10 cc. fermented seed extract, 72 hours at 38° C	0.0
10 cc. maltose solution, 10 cc. fermented seed extract, 72 hours at 38° C	+23.2
10 cc. maltose solution, 10 cc. fermented seed extract heated, 72 hours at 38° C	+23.4

The maltose solution was a 10 per cent solution. Euler[13] makes the statement—

In both the animal and vegetable kingdoms maltose almost always accompanies the diastases, from which it cannot often be separated.

However, not even the fermented seed extract which showed diastatic activity shows any maltase activity. This appears to be one of the rarer cases of diastases unaccompanied by maltase.

SUMMARY

The pulp surrounding the cacao bean contains a greater number of enzymes than the fresh bean itself. The pulp shows activity for the enzymes casease, protease, oxidase, raffinase, and invertase.

The fresh bean gave reactions for casease and raffinase, and very strong reactions for oxidase.

The fermented bean reacted for casease, protease, oxidase, diastase, raffinase, and invertase. The fermented bean shows the presence of protease and invertase, both of which are absent in the fresh bean, but present in the pulp. These must have penetrated the membrane surrounding the bean during fermentation. Diastase is present, but absent in the extracts from the fresh bean and from the surrounding pulp. This has been developed in the bean itself during the process of fermentation.

Therefore the conclusion is reached that the presence of these enzymes undoubtedly influences the character of the fermentation and that temperature control during fermentation is necessary in order that they may not be destroyed.

This cacao was furnished me by Mr. Jacobson, of the Bureau of Agriculture, Manila, to whom I wish to express my thanks.

[13] General Chemistry of the Enzymes (1912), 19.

WATER SUPPLIES IN THE PHILIPPINE ISLANDS: II[1]

By George W. Heise

(From the Laboratory of General, Inorganic, and Physical Chemistry, Bureau of Science, Manila, P. I.)

CONTENTS

PRESENT STATUS OF THE WORK ON PHILIPPINE WATER SUPPLIES

In spite of great progress made since the American occupation in the matter of providing the people of the Philippines with pure drinking water, the present state of affairs is still far from satisfactory. Whole provinces continue to be dependent on surface waters of doubtful purity, and even in many localities where safe water is obtainable, a large number of people, through ignorance or indifference, utilize more conveniently located and less wholesome sources. In addition, there are certain areas in which both surface and ground waters are not potable, where the people are forced to depend almost entirely on rain water for drinking purposes. As the rain water is often carelessly collected and improperly stored, it is hardly to be considered a safe water supply.

However, a marked movement at the present time for better conditions is evident both in the development of new sources of good water and in the gradual elimination of dangerous water supplies. The Insular Government has greatly stimulated the drilling of deep wells by continuing to assume the entire cost of unsuccessful public wells and two thirds of the cost of all successful installations, and has made large sums of money available for water-supply projects. Such progress has been made that it is estimated [2] that deep-well water is now available to over one sixth of the entire population of the Islands.

[1] Received for publication April 15, 1915.

[2] Vickers, *Quar. Bull. P. I. Bur. Pub. Works* (1914), 2, 28.

During the year 1914 the Bureau of Public Works alone drilled 120 deep wells, 103 of which were successful, while provinces and private individuals drilled perhaps an equal number. The total number of deep wells in the Islands is over 1,000.

The progress of the movement for better water supply may be judged from the fact that over 50 water-distribution systems are already in operation, and that many municipalities, some of them very small, are planning to install systems in the near future. Two recently completed installations—at Boac, Marinduque, and Sariaya, Tayabas—are typical of what can be done in small towns. The former supplies from 3,000 to 4,000 people and derives its water from two deep-pumping wells; the latter supplies about 4,000 people and takes its water from a large spring on Mount Banahao, 6 kilometers from the town. The largest single project being developed at present is that of Iloilo, to which reference has already been made,[3] where an installation capable of supplying 55,000 people is being planned.

LABORATORY WORK

The Bureau of Science passes judgment on all newly developed public water supplies before they are made available to the public, and as there is no water laboratory outside of Manila, this central laboratory has been receiving a steady influx of water samples from all parts of the Islands. During the year 1914 about 200 chemical analyses and 2,100 biological examinations were made.

As many of these samples are not properly taken, are accompanied by insufficient data concerning the sources from which they come to justify conclusions concerning their potability, and are very old when they reach the laboratory, owing to the poor transportation facilities in some parts of the Islands, their sanitary analysis is of doubtful value. Under such conditions the judgment of water, not an easy task at best, often becomes impossible, especially as the insufficiency of the work done on Philippine waters and the diversity in quality of waters to be found even in restricted areas have made it impossible to establish fixed standards.

It is being generally recognized[4] that single "sanitary analyses" of waters are often of little value, especially when the analyst does not take the sample. The failure of the "conventional grind of nitrogen determinations" is amply demonstrated

[3] *This Journal, Sec. A* (1915), 10, 65.
[4] Cf. Barnard, *Eng. Rec.* (1913), 68, 297.

by the analytical records of the Bureau of Science, where waters known to be uncontaminated range as high as 20 or more parts per million in free ammonia content. Therefore it seems desirable to eliminate nitrogen determinations in most cases and to limit our efforts to the determination of normal mineral constituents, supplemented by biological examinations whenever feasible, until such time as our increased knowledge of Philippine waters and of tropical conditions shall justify other methods.

The analytical data obtained in the Bureau of Science laboratory during 1914 are contained in Tables III to V at the end of this paper. All results are given in terms of parts per million unless otherwise stated.

FIELD WORK

It soon became evident that a field survey offered the best solution of the problem of obtaining the most information concerning Philippine water supplies with the least possible expenditure of time and money. Accordingly a simple chemical field outfit, based on that described by Leighton,[5] was constructed. Field methods leave something to be desired, so far as accuracy is concerned, but it is thought that they have been more than justified by the volume of reasonably accurate work done in a comparatively short time, and by the intimate knowledge of local conditions made possible by the field trips.

In addition to the chemical equipment, the field outfit included a small portable bacteriological kit, consisting of Petri dishes, a case of sterile pipettes, and tubes of litmus lactose agar and lactose bile agar. A plate culture on litmus lactose agar gave an approximate bacteria count and showed the presence or absence of acid-forming bacteria; a tube culture in lactose bile agar indicated the presence or absence of lactose-fermenting organisms. The uniformly high temperature encountered in most parts of the Islands enables fairly concordant results to be obtained without the use of an incubator. Pipettes were separately wrapped with gauze and carried in a tinned cylinder; hence it was easy to sterilize them even in the field. The Petri dishes were simply wrapped in paper, in packages of six, before being sterilized; they remained uncontaminated for weeks. Bacteria counts were generally made at the end of both twenty-four- and forty-eight-hour intervals.

The field investigations were, in the main, confined to three islands: namely, Mindoro, Cebu, and Panay. The analytical

[5] *U. S. Geol. Surv., Water Supply Paper* (1905), 151.

data are tabulated at the end of this paper: Table VI dealing with deep wells, Table VII with springs, and Table VIII with surface and miscellaneous supplies.

DEEP WELLS

The following extract from an article by Vickers[6] gives a good summary of the Philippine deep-well situation:

The cost of a sufficient number of machines of the deep-well type was in excess of the funds available at that time [1906] and the Insular Government met this demand for new equipment by designing and constructing several small hand-power outfits, known as "jet rigs." It was soon demonstrated that these outfits, owing to their simple design, could be operated to advantage by native workmen in localities where it was not necessary to drill to depths greater than 200 to 300 feet, and where no rock or difficult strata had to be penetrated; * * *. The demand for this class of equipment increased until 1911, when 45 jet rigs had been constructed and equipped for operation and practically every province, wherein they could be successfully operated, had been supplied with from one to five outfits. It was found, however, that in many localities the deep-well or steam-power rigs were necessary for successful operation, and the demand for wells in these localities was so insistent and increased to such an extent that additional equipment of this class was added from time to time, until 25 deep-well machines had been purchased. Funds for the operation of both jet and deep-well rigs were provided entirely by Insular appropriations until 1910; at this time a coöperative policy was adopted whereby one-third of the cost of drilling was borne by the provinces or municipalities for which the work was done and two-thirds by the Insular Government. The deep-well rigs were operated by the Bureau of Public Works as before, while many of the jet rigs remained under the supervision of provincial officials. This policy proved to be satisfactory and is still being followed.

A large number of the wells drilled in the Islands have a natural flow, some of them supplying enormous quantities of water, notably, the famous gusher at Bayambang, Pangasinan, which supplies 1,000,000 gallons daily. The water from the latter is distributed through two main supply pipe lines, one leading to the military post at Camp Gregg, and the other to the town of Bayambang. In many of the provinces it is necessary to drill wells ranging from 600 to 800 feet in depth in order to obtain good water. In the town of Wright, Samar, good water was not encountered until a depth of 1,025 feet was reached, when flowing water of excellent quality was tapped. This well is the deepest in the Islands which supplies good water. A number of wells have been drilled to greater depths, however, but in every case except the one mentioned above salt water was encountered below 1,000 feet. The deepest well ever drilled in the Islands was located on the trade school grounds at Iloilo, and was sunk to a depth of 2,285 feet without encountering fresh water. An interesting feature in connection with some of the wells is the effect the ocean tide has upon the fresh-water flow, one remarkable instance being the

[6] *Quar. Bull. P. I. Bur. Pub. Works* (1914), 2, 26.

well at Bauan, Batangas, drilled to a depth of 298 feet, which flows 250 gallons per minute 18 inches above the ground surface at high tide, and 50 gallons per minute at low tide at the same elevation; in other words, the flow at high tide indicates an increase of 400 per cent over the flow at low tide, notwithstanding the fact that analyses of water samples collected at both high and low tide give identical results and show the water to be potable and free from salt-water contamination.

In many borings, especially near the coast, brackish water is encountered during the first 30 to 70 meters, even though fresh water may be found at low levels. In some rather exceptional cases, in which salt water was encountered at great depths, continued drilling developed a supply of fresh water. At Wright, Samar, salt water was found at 180 to 215 meters; this was cased off, and drilling was continued. At 312 meters fresh water was found under sufficient pressure to cause a flow, which, although slight even at ground level, did not cease entirely at 12 meters above the earth's surface.

The deep-well waters are so lacking in uniformity that generalizations regarding them are difficult, if not impossible, at the present time. Very frequently wells drilled within a few meters of each other may encounter entirely different strata, and the water from them may be markedly different. Two wells drilled on the Bureau of Science grounds within 75 meters of each other are very different, both in regard to the water-bearing strata from which their supplies are derived, and the quality and quantity of water encountered. Well 1 runs 725 parts per million total solids and 70 parts chlorine; well 2 runs 500 parts total solids and 12 parts chlorine. Three wells in Iloilo (at the Iloilo Electric Company's works), located within about 15 meters of each other and drilled to about the same depth, show similar irregularities, two being approximately similar but differing from the third.

The minimum temperature of deep wells drilled in the lowlands is about 28° C., but the temperature range is great.

The deep-well waters range in total solids content from about 120 (well 129, Nueva Caceres, Ambos Camarines) to 8,200 parts per million (Janiuay, Iloilo), and in chlorine content from 1.5 (San Jacinto and Binalonan, Pangasinan) to 4,471 (Janiuay, Iloilo).

The highest free ammonia content recorded is that of a well at Los Baños, Laguna, 70 meters deep, which showed 32.7 parts per million. The reason for this abnormal content is not apparent.

In general, the deep wells show a high degree of bacteriological purity. The flowing wells, so far as known, are all sterile or very nearly so, and deep-pumping wells seldom show any marked degree of bacterial pollution except where the equipment is defective or carelessly handled.

SURFACE WELLS

Ordinary surface wells still furnish a large share of the water utilized in the Philippines and constitute a great menace to public health and an obstacle to sanitation. Numerous causes contribute to make these wells dangerous in the extreme, among which may be mentioned the fact that most of them are uncovered and many are uncurbed; the general method of drawing water from them is with a rope and bucket; they are located in crowded barrios; clothes are washed at the well side, and there is a general neglect of sanitary precautions.

The status of the surface well is clearly demonstrated by the results of biological examinations made in the field, as illustrated by Table I.

TABLE I.—*Bacteriological field examinations of surface wells, 1914.*

No.	Province and town.	Bacteria.		
		Approximate number per cc.	Acid formers.	Gas formers.
37	Cebu, Balamban	(a)	+	+
17	Cebu, Cebu	2,000	+	+
25	-----do	4,000	+	+
26	-----do	4,000	+	+
27	-----do	725	+	+
38	-----do	1,300	+	+
39	-----do	5,000	(b)	+
40	-----do	60	—	—
41	-----do	2,000	+	+
42	-----do	(a)	(b)	+
132	Iloilo, Iloilo	1,500	(b)	----------
133	-----do	2,000	(b)	----------
131	Iloilo, Iloilo (Molo)	2,000	—	----------
136	-----do	1,500	+	----------
6	Mindoro, Pola	(a)	+	+
7	-----do	(a)	+	+

[a] Excessive. [b] Few.

The data in Table I were obtained from wells examined in the course of the field trips. Fifteen of the sixteen sources listed gave unmistakable evidence of pollution on a single examination, while the sixteenth was so located that contamination

at some time seemed a foregone conclusion. Admitting that the data on which to base conclusions are limited in quantity, the facts that the results obtained by single examinations were so uniform, and that the examinations were made during the dry season when contamination was least likely to occur, show how unsafe surface wells in the Philippines are. It would probably be conservative to say that the water from over 80 per cent of the wells is unfit to drink, and that very few of the wells are safe throughout the year.

Chemically their waters show no marked peculiarities, and they have not been studied sufficiently to justify generalizations. Their quality doubtless varies greatly during different seasons. The surface wells listed, with the exception of a few located so near the ocean that they were obviously contaminated by sea water, range in total solids content from 164 to 1,230 parts per million, and in chlorine content from 5.5 to 436 (average, about 150), while the highest free ammonia content noted is 0.64.

RIVERS AND FLOWING STREAMS

No systematic study of water courses has yet been attempted. Doubtless as manufacturing industries develop, the question of the quality of the water of streams will increase in importance, but at present comparatively little river water is used. A comparatively small amount is being used for boiler purposes, but aside from this, practically the only water whose quality becomes a matter of consideration is that of the rivers which serve as sources of municipal water supply, as at Manila and Cebu.

The stream waters analyzed, with the exception of tidal rivers and water courses known to be contaminated, ranged from 45 to about 550 parts per million in total solids and from 2 to 150 in chlorine, and showed a maximum free ammonia content of 0.125 part per million.

SPRINGS

The contribution to the study of spring waters during the past year has been meager. There is a marked tendency to utilize spring waters more than formerly, notably in small towns so situated that such waters can readily be conveyed to them. In Cebu Province, where springs are numerous, there are at least sixteen towns which developed projects involving the utilization of springs for municipal supply.

As the country develops, many springs will doubtless become

popular as health resorts. At present only a few springs are much visited. The Insular Government has erected a bath at Sibul Springs, and this place, as well as Los Baños and Pagsanjan, has many patrons. The Los Baños water is carbonated, bottled, and sold.

Some of the springs are so saline that the recovery of salt from them is an easy and profitable undertaking. A number of springs in Nueva Vizcaya are now so utilized.

The waters vary widely in quality. The total solids content ranges from 24 to 6,025, and chlorine from 0.7 to 3,120, while the maximum free ammonia content is 6.2.

WATER SUPPLIES OF MINDORO

Mindoro, one of the largest of the islands of the Archipelago, is very sparsely populated. It has between 60,000 and 70,000 inhabitants, who live near the coast. The interior has been little explored and is uninhabited except for from 6,000 to 7,000 uncivilized Mangyans.

The surface waters in many districts, in addition to being unsafe, are so brackish that they are unpleasant to the taste, and a great deal of trouble has been experienced in providing the people of Mindoro with water. However, in recent years the water supply has been greatly improved by the installation of jet-rig wells by the provincial authorities.

A brief field trip was made to Mindoro for the purpose of investigating the proposed municipal water supply of Calapan, the provincial capital, but the scope of the investigation was later enlarged to include several other towns.

Calapan.—Calapan, a town of 9,000 inhabitants, is extremely unfortunate in regard to water supply. The surface wells are brackish, the river is affected by the tides, and good springs are lacking. All attempts to secure a supply of potable water by sinking deep wells have been without success. Limited amounts of brackish water are found at slight depths in drilling operations. Black sand containing sea shells is found underlying the soft coralline formation near the surface, until, at a depth of about 30 meters, a hard rock stratum about 30 centimeters thick is encountered. Penetrating this rock the drill suddenly sinks, and very hot, salty water rises in the drill hole to about ground level. The water from the well at the public market at Calapan showed a temperature of 40° C. Although clear and colorless at first, it became yellow and turbid on standing for a short time, due to the escape of carbon dioxide and the resulting precipitation of calcium and iron salts.

A large spring about 4 kilometers from Calapan, having an estimated flow of 55 liters per minute throughout the dry season, has been proposed as a source for the town supply. Although the water is potable, the spring is so located that there might be difficulty in guarding it from future contamination, and its elevation is so slight that a pump would probably have to be installed to make the water available for municipal supply.

There were formerly a number of sulphur springs at Calapan which were used as baths. At the time of examination the place pointed out as the site of the springs was a small swamp, which contained a few small springs of clear saline water having no odor of hydrogen sulphide. The temperature of the water was 50° C.

Naujan.—Naujan, which has a population of 7,000, has been supplied with water through the efforts of the provincial authorities. Four flowing wells have been drilled, which give abundant quantities of excellent water; two of these wells are cased with 3-inch pipe and two with 2-inch pipe. Unfortunately some local prejudice seems to persist against their use, and the populace as a whole still depends in a large measure on surface supplies and on rain water; the latter, owing to improper methods of collection and the custom of storing it in large uncovered earthenware jars, is of questionable purity.

The artesian waters, it is claimed, have the odor of hydrogen sulphide at some seasons of the year, which may account for their lack of popularity.

Pola.—Pola is a town of less than 3,000 inhabitants, depending for its water supply on open dug wells or shallow bored or "punched" wells. The supply is very unsatisfactory, as it is somewhat brackish and for the most part subject to contamination at all times. All the wells examined biologically gave evidence of sewage pollution. Tiguihan River, a mountain stream located a short distance from the town, promises to be a satisfactory source of water. It drains an apparently uninhabited area, has a volume large enough to insure an adequate supply, and appears to have sufficient elevation to enable the installation of a direct-gravity system. The water has an excellent local reputation and seems to be entirely suitable for domestic purposes.

Pinamalayan.—Pinamalayan has a population of over 6,000, and is greatly in need of a municipal water supply, as the surface wells are all brackish and unsafe. The attempt to secure deep wells has been unsuccessful, as only salt water was encountered in any quantity, although drilling was continued to a depth of

about 75 meters, the approximate limit of the well-drilling outfit used. The geologic formation is estuarine and littoral, consisting of clay, sand, and shells with intercalated layers of sandy coral. Logs with the bark still adhering were encountered at a depth of 65 meters.

There is a small stream about 2.5 kilometers from the town which might be utilized for municipal supply if properly guarded from contamination; at any rate, the chemical character of the water and the location of the stream present no obstacles to the development of the project.

A short distance from the old town of Pinamalayan, and farther inland, a new town site is being developed. Four wells were recently drilled here. A good flow of water was obtained at a depth of about 50 meters. The water is of good quality and should prove suitable for most purposes.

WATER SUPPLIES OF CEBU

Good progress has been made in supplying Cebu Province with potable water. The city of Cebu has recently completed a reservoir and water-distribution system which is one of the finest municipal waterworks in the Philippines. Excellent springs are abundant and are much used in spite of the fact that many of these are so located that they are not available to very many people. At the present time nearly twenty towns have well-developed projects for utilizing springs, as shown by Table II, the data in which were supplied (November, 1914) by the provincial district engineer's office. The money necessary for some of these projects has already been appropriated.

TABLE II.—*Data for proposed water supplies, Cebu Province, 1914.*

Municipality.	Name of spring.	Population to be supplied.	Flow per minute.	Per capita supply.	Pipe line.	Elevation above town.
			Liters.	*Liters.*	*Meters.*	*Meters.*
Argao	Kabagohan	5,000	75	25	3,600	110.00
Barili	Mantayapan	5,000	1,900	75	4,450	131.68
Carcar	Guadalupe	5,000	100	30	3,100	18.00
Catmon		1,500	95	90	1,700	42.00
Ginatilan		2,000	40	55	2,320	201.40
Malabuyoc		1,300	275	55	1,340	9.42
Moalbual		2,000	1,900	75	4,040	32.61
Naga	Jugan	1,981	55	65	1,430	77.00
Pilar		1,000	35	105	2,314	58.25
Poro	Cantaway	1,000	55		1,820	138.49
Samboan	Din-ak	2,000	480		1,226	30.09
Sibonga	Balaas	5,000	195	40	4,703	105.00
Tudela	Guinawitan	1,000	65		1,640	95.13

At least one additional town, Asturias, has since started a similar town project.

Attention has already been directed [7] to a special study of typical springs made by Mr. V. Q. Gana in 1908.

A rather peculiar spring is situated in the city of Cebu on the beach near the old leper house. The water from this spring—or, more properly, series of springs—is fresh as it issues from the sands of the seashore, although the springs are entirely covered at high tide. Abella mentions [8] a spring situated on the beach at Oslob, which is submerged at high tide, so that people are obliged to wade out into the ocean to collect the water. At low tide the flow is greatly decreased.

Approximately thirty successful deep wells have been drilled in Cebu Province by the Bureau of Public Works alone; however, about one half of these are located in the city of Cebu. Strangely enough, although the Province of Cebu is mountainous, only one flowing well (at Argao) has been developed, and this flows only at high tide. The installation of deep wells has done much toward improving local health conditions.

Although unsafe surface waters still constitute a large percentage of the available water supply, an active campaign against surface wells inaugurated by the district health officer is rapidly lessening the evils which may be traced to the use of impure water.

The field trip in Cebu included one journey south from Cebu to Argao and another from Cebu west to Toledo and north from Toledo to Asturias.

City of Cebu.—The main source of water supply for the city of Cebu is now the Osmeña Waterworks, completed in 1912. This installation, in addition to the distributing system in the city and a concrete distribution tank, comprises a reënforced-concrete dam and spillway located in a narrow gorge at Buhisan, about 6 kilometers from the town. Between 1,000,000 and 1,500,000 cubic meters of water are impounded by the dam, representing a supply, based on the water-consumption data for Manila, of at least one hundred days for the city of Cebu (population, 60,000). The water is clear to begin with at almost all times of the year, and the great storage capacity of the reservoir, supplemented by that of the distribution tank (over 15,000 cubic meters—that is, almost two days' supply), gives ample oppor-

[7] *This Journal, Sec. A* (1914), 9, 273.

[8] Rapida Descripcion . . . de la Isla de Cebu. Madrid (1886), 87.

tunity for sedimentation and purification. The elevation of the distribution tank is such that the water pressure in the Cebu city mains is about 7 atmospheres.

The water is neither filtered nor chemically treated at present, and it does not appear likely that it will need treatment, at least for some time to come. As it now leaves the taps in the city, it is clear and colorless and very low in bacterial life. It is high in iron, which may lead to the growth of *Crenothrix* later on, but so far no trouble from that source has been experienced.

The deep wells in the city of Cebu, about fifteen in number, are from 25 to 36 meters deep, at which depth abundant supplies of good water are encountered. In no case under observation did the wells of this type show signs of sewage contamination. The strata encountered in well-drilling are alluvium overlying coral, none of the successful wells, so far as known, having penetrated the latter. There is one artesian well on Cauit Island, near Cebu, which is 90 meters deep and flows only at high tide. Its salt content has almost doubled since 1906, when the well was installed.

After the installation of the municipal water system, the health authorities started a vigorous campaign against surface wells, with the result that the majority have already been closed and the others will shortly be filled up and abandoned. Considerable local opposition to the action of the authorities was developed, as people naturally object to the destruction of wells, which represent considerable investment, and whose purity they have never learned to question. Among some classes of people there was even a marked antipathy to the use of the city water. However, that the campaign was necessary was clearly demonstrated by the district health officer, who traced the relationship between the spread of cholera and the use of well water, showing, among other things, that excessive rainfall, and consequent pollution of the surface wells, produced an increase in the number of cholera cases in times of epidemic. As public hydrants have been placed in those parts of the city where the people are too poor to pay for the water installations, and as no wells were ordered closed until the city water supply was made available, no real hardship has been imposed on any one. The marked improvement in local health conditions has more than justified the efforts of the health officials.

Although there could be little question of the status of wells in general, it had been hard to get definite and conclusive evidence against suspicious sources, and people had resented having wells

closed for no better reason (to them) than an arbitrary order from the authorities. There was no laboratory available for water examination and no persons to do such work, so the arrival of our small portable outfit proved of assistance to the local health authorities. The character of the wells may be inferred from the fact that although the investigation was conducted during the dry season the wells, almost without exception, showed evidence of pollution on a single examination.

The west coast of Cebu.—For the most part the inhabitants of the west coast of Cebu are still dependent for their drinking water on rain-water cisterns and on surface wells, many of them brackish. There are a number of excellent springs, but many of them are not conveniently located and have not yet been developed, and many are not cared for at all or are so poorly safeguarded that their water supply is not above suspicion. Doubtless many towns could install small municipal water systems at moderate cost, deriving their supply from springs in the vicinity.

The attempt to improve the water supply by means of deep wells has not met with unqualified success. At Barili and Moalbual drilling was continued to 225 and 300 meters, respectively, but only salt water was encountered. At Toledo the experience has been more fortunate. Boring has been continued to 55 meters, and potable water, under sufficient pressure to rise within 3 meters of ground level, has been developed. However, one of the Toledo wells turned brackish within the last six months.

The towns of Asturias and Balamban are dependent in a great measure on surface supplies and rain water, although there are excellent springs in the vicinity which could be developed for municipal supply.

The east coast of Cebu.—In addition to Cebu itself, the towns visited in the course of the trip along the east coast of Cebu were Talisay, Minglanilla, Naga, Carcar, Sibonga, and Argao. All of these, except Carcar and Argao, are almost entirely dependent on rain water and surface supplies. In Minglanilla, it is true, there is a large spring, which, although unfortunately located with respect to surface drainage and showing a suspiciously high bacteria count, probably yields the best water available in that district. The Argao well furnishes good potable water from a depth of 150 meters, but unfortunately only comparatively few of the town people use it exclusively. There are two deep wells in Carcar, one owned by the railroad, the other by private individuals, both of which furnish water which is chemically satisfactory.

WATER SUPPLIES OF PANAY

Iloilo.—The general features of the water supply situation of Iloilo have already been referred to,[9] so that only some of the more significant details need be discussed here. The water supply problem of Iloilo Province presents the characteristics and difficulties encountered in other parts of the Archipelago, with the added complication that, so far, no really good artesian supply has been developed. In the city of Iloilo the problem has always been exceedingly perplexing, because the surface wells are all brackish, and except for rain water all natural waters used for drinking purposes have to be carried for considerable distances.

Many deep wells have been drilled, most of them in the city of Iloilo, with rather interesting results. Those in Iloilo, the majority of them flowing wells, are between 80 and 90 meters deep, no good water having been found at greater depths in this locality. The deepest well on Panay is at Janiuay. It is a flowing well 375 meters deep, which yields an intensely salty water. The deepest well whose water might be considered potable is about 165 meters deep, located at Santa Barbara.

Chemically the artesian-well waters show marked peculiarities. They are all brown, charged with gas, and as already pointed out,[10] have an abnormally high free ammonia content. All of them are brackish,[11] the well at Santa Barbara showing the lowest chlorine content (240 parts per million). A marked peculiarity is the absence of sulphates. Most of the waters are very hard and high in mineral salts, so it is interesting to note that the Santa Barbara well, with a total solids content of over 1,000 parts per million, contains no calcium, and that the Mandurriao and Molo wells are very low in calcium content.

With the present unsatisfactory character of the deep-well waters it seems probable that rivers and springs will have to be utilized to a much greater extent than they are now, and that greater care will have to be exercised in safeguarding available sources.

Although rain water, often improperly collected and carelessly stored, is hardly a source above suspicion for domestic purposes,

[9] *This Journal, Sec. A* (1915), 10, 65.

[10] Ibid. (1914), 9, 339.

[11] It is interesting to note that in Iloilo many people, among them Americans and Europeans, have accustomed themselves to drinking the deep-well water (total solids content, 2,000±; and chlorine content, 800–900) without experiencing any noticeable ill effects.

it has occasionally been made an excellent water supply, notably in the city of Iloilo, where a number of properly constructed cisterns are giving good results.

At Capiz, where the surface supplies are uniformly bad and well drilling has resulted in failure, the construction of a cistern large enough to supply the residents of the city with drinking water is being contemplated.

WATER SUPPLIES OF MANILA

The problem of adequately supplying the city of Manila with water is still troublesome, and funds for making improvements are not available. It appears to be extremely difficult to impound sufficient water at Montalban to last throughout the year, due in a great measure at least to leakage, which the decomposed and water-worn character of the limestone formations at the site of the dam makes unavoidable. For the last two years it has been necessary to supplement the Montalban supply with water from Mariquina River, a proceeding which has proved a serious menace to public health. The total storage capacity is too small to allow of much sedimentation, and as no provision for filtration has been made, water which is still carrying varying amounts of suspended matter finds its way into the city mains. Large quantities of foreign substances are thus allowed to accumulate in the pipes, and the attempts to purify the water with chloride of lime are seriously interfered with. During the period in which chlorination has taken place, the water, as examined at various points in the distributing system, has shown, with increasing distance from the chlorination station, first a marked decrease in bacterial count and frequently the absence of amœbæ and colon-group bacteria in 2 cubic centimeters of samples of water, then a gradual rise in count, and the reappearance of the organisms mentioned. Day after day the bacteria count at the Bureau of Science tap has been in excess of that of the water at the reservoir, although, at intermediate points, the bacterial count has been exceedingly low. Frequent flushing out of the distributing system is undoubtedly of great benefit, but in itself is not enough to cause much improvement. In the absence of reservoirs large enough to ensure adequate sedimentation, a rapid sand filter, with proper equipment for previous coagulation whenever the water is turbid, is an imperative present necessity.

TABLE III.—*Analyses of water from deep wells, 1914.*

[P=pumps; F=flows.]

Tracing No.	Laboratory No.	Well No.	Location.	Depth.	Month.	Diameter.	Water-bearing materials.	Capacity per minute.	Height of water above (+) or below (—) surface.	Depth of casing.	Physical characteristics.
				Meters.		*Inches.*		*Liters.*	*Meters.*	*Meters.*	
1	118767		Agusan, Cabadbaran								
2	119182		do								Normal.
3	119419	680	Albay, Bato (barrio Cabugao)	50	October		Gravel, tuff, andesite	P 50		43	Slight sediment.
4	118261	601	Albay, Tabaco	123	February		Volcanic fragments and tuff.	F 57		122	Brown.
5	118685	601	do	123	May		Same as No. 3	F 57		122	
6	118656	615	Albay, Virac	351	do		Limestone and fine limestone sand.	P 23		266	
7	118814	648	do	61	do		Limestone	P 68	— 4.5	60	
8	119202	657	do	267	August		do	P 60		236	Normal.
9	119112	443	Ambos Camarines, San Jose No. 2.	36.6				P 68			Very turbid.
10	118046	584	Batangas, Batangas	163	December		Tuff, clay, sand	P 151		146	Turbid.
11	119051	670	Batangas, Batangas (Calle Jaena).	97	July		Tuff	P 378		74	Normal.
12	119111	673	Batangas, Batangas (Government building).	89	August	6	Sand	P 378		78	Do.
13	119211	681	Batangas, Batangas	140	September	6	Sandstones	P 378		128	Do.
14	119293	686	Batangas, Batangas (Calle P. Burgos.	145	do	6	Sand	P 189		136	Slightly turbid.
15	119420	690	Batangas, Batangas	142	October	6	do	P 113	— 3.7	128	Normal.
16	119581	697	do	130	December	6	Brown sand rock	P 132	—27	116	Do.
17	118864	638	Batangas, Bauan (barrio Asias)	117	June		Tuff	P 132		46	
18	119002	638	do	117	July		do	P 132		46	
19	119134	638	do	117	August		do	P 132		46	Normal.

20	119078	640	Batangas, Bolbok	171	July	4.5	Limestone with tiny shells	F 18		143	Yellow brown.
21	119255	672	do	189	September		Tuff, gravel, limestone fragments.	F 56	+ 7.5	139	Normal.
22	119564	688	Batangas, Bolbok (barrio Sico)	184	December	4.5	Sand and gravel	F 75		180	Colored and slightly turbid.
23	118223	577	Bohol, Inabanga	136	January	4.5	do	P 37		130	Yellow.
24	118408	192	Bohol, Tagbilaran	207	March		Sand	P 227			
25	118556	619	do	39	April	8	Coral rock	P 378		28	Odor of H_2S; some sediment.
26	118110		Bulacan, Marilao								
27	118047	586	Bulacan, Baliwag, Camboag	172	January		Clay, gravel, etc.	F 113		157	Normal.
28	118305	608	Bulacan, Baliwag, Tanauan	137	February	4.5	Clay, sedimentary gravel	F 75		136	Do.
29	118596	616	Bulacan, Baliwag, Sabang	137	April		Clay, gravel, tuff	F 227		134	
30	118228		Bataan, Pilar (Calle Kansas)		February						Normal.
31	118228		Bataan, Pilar (Calle S. Jose)		do						Do.
32	118228		Bataan, Pilar (Calle S. Pedro)		do						Do.
33	118228		Bataan, Bataan Pequeño (Calle S. Jose).		do						Do.
34	118228		Bataan, Santa Rosa (Calle Mabolo).		do						Do.
35	118228		Bataan, Santa Rosa (Calle Masantol).		do						Do.
36	119601		Bataan, Calle Pañganiban, Orion.		December						Do.
37	119601		Bataan, Calle Real, Orion		do						Do.
38	119601		Bataan, Calle P. Gomez, Orion		do						Do.
39	119601		Bataan, Calle P. Gomez, Orion		do						Do.
40	118593	,2	Butuan		April						
41	119058	659	Cavite, Talipapa, Imus	151	July		Tuff, sand, clay	F 378		135	Normal.
42	119172	678	Cavite, Imus	91	August	4.5	Sand, tuff	F 56; P 568	+ 1	77	Do.
43	119505	684	do	267	November	4.5	Tuff etc	P 75	−21	251	Normal; slight sediment.
44	118366	611	Cavite, Santa Isabel, Kawit	119	March		do	F 60; P 302			
45	118686	631	Cavite, Kawit	122	May		Tuff and sand	F 22; P 378		95	
46	118813	646	Cavite, Binacayan, Kawit	142	June		Clay, sand, tuff	F 34; P 227		125	Normal.

TABLE III.—*Analyses of water from deep wells, 1914*—Continued.

Tracing No.	Laboratory No.	Well No.	Location.	Depth.	Month.	Diameter.	Water-bearing materials.	Capacity per minute.	Height of water above (+) or below (—) surface.	Depth of casing.	Physical characteristics.
				Meters.		*Inches.*		*Liters.*	*Meters.*	*Meters.*	
47	118166	599	Cavite, Noveleta	105	January	4.5	Tuff, clay, sand	F 45		93	Do.
48	118262	604	Cavite, San Juan, Noveleta	106	February	6	Tuff	F 94; P 378		97	
49	118555	617	Cavite, San Jose, Noveleta	103	April		Tuff and sand	F 11; P 227		34	
50	118661	146	Capiz, Capiz	306	May		Shale	P 75	—21		
51	119411	374-A	Cagayan, Tuguegarao	390	November			P 113			Turbid.
52	118277		Cebu, Bagumbayan, Cebu	20	February						Normal.
53	119237	682	Cebu, Toledo	15	September	6		P 264	—18	13	Slightly brown.
54	119323	689	do	54	do	8	Black sand containing shells.	P 60	— 8	42	Slightly turbid.
55	118167	600	Iloilo, Iloilo	80	January			F 45		80	Yellow brown.
56	118057	597	do	80	December						Brown.
57	119138	112	Iloilo, Sta. Barbara	157	August	6	Sand	F 151		80	Brown; slight sediment.
58	118119	587	Laguna, Famy	117	January	8	Gravel	F 68	+ 2	114	Normal.
59	119055	671	Laguna, Mabitac	99	July		Clay, tuff	F 113; P 265		93	Do.
60	119196	674	Laguna, Santa Maria	145	September		Clay fragment, limestone	F 64	+ 3.5	137	Do.
61	119382	685	Laguna, Pagsanjan	91	October		Clay, tuff, etc	F 605		90	
62	118409	576	La Union, Bangar	143	March		Sand, gravel, plutonic, volcanic.	P 246	— 1	231	
63	119050	623	La Union, Balaoan	266	July		Clay, limestone, shale (?)	P 37		269	Brown; much sediment.
64	119256	623	do	266	September		do	P 37		269	Do.
65	119326		Manila, 1338 Calle Juan Luna		October						Normal.
66	118752		Manila, Escolastica's College		May						
67	118904		Manila, Philippine General Hospital.		June						
68	118904		do		do						

69	118676		Manila, Division of Cold Storage, Bureau of Supply.		May						
70	118826		do		June						
71	119084		do		July						Do.
72	119348		do		October						Do.
73	119426		do		November						Do.
74	119544		do		December						Do.
75	119615		do		do						Do.
76	118013 118128		Manila, Calle Principe (Yangco Steamship Co.).		January						Do.
77	119407	410	Misamis, Cagayan		November						Turbid.
78	118644	484	do	169	May		Gravel and pumice	P 227		167	
79	118958	613	Nueva Ecija, Aliaga	153	July		Tuff, clay, gravel	F 41	+ 4.5	142	
80	119074	662	Nueva Ecija, Cuyapo	132	do		Clay, sand	F 94		132	Normal.
81	119257	677	do	111	September	4.5	Sand	F 151	+ 0.86	111	Do.
82	119595	687	do	170	December	4.5	Sand and gravel	F 7; P 151		170	Do.
83	119581	691	Nueva Ecija, Cabanatuan	186	do	4.5	Gravel	F 45		185	Do.
84	118094	538	Occidental Negros, Murcia	318	do	4.5	Fine volcanic sand	P 94		209	Turbid, yellow.
85	119036	594	Occidental Negros, San Carlos	247	July					245	Normal.
86	119185	594	do	247	September	6	Sand and gravel	P 113	— 6.1	245	Brown.
87	118529	597	Occidental Negros, Bacolod	161	March		Tuff	P 151		164	
88	118597	629	do	35	April		Tuff	P 75		33	
89	118654	633	do	44	do			P 265		44	
90	118687	634	do	36	May		Tuff and sand	P 75		37	
91	118905	635	do	38	June	4.5	do	P 113		30	
92	118906	650	Occidental Negros, Bacolod (Lacon and Rizal).	30	do		Volcanic sand, tuff	P 75		28	
93	118907	653	Occidental Negros, Bacolod (barrio Magdalena).	36	do		do	P 75		27	
94	119186	653	do	36	September		do	P 75		27	Normal.
95	119187	661	Occidental Negros, Bacolod	59	August		Sand	P 56	— 3.3	58	Yellow, turbid.
96	119188	664	Occidental Negros, Sumog, Bacolod.	100	do	4.5	Sand ?	P 94		84	Normal.
97	118410	588	Oriental Negros, Dumaguete	136	March		Sand, diorite, and andesite.	F 151		141	

TABLE III.—*Analyses of water from deep wells, 1914*—Continued.

Tracing No.	Laboratory No.	Well No.	Location.	Depth.	Month.	Diameter.	Water-bearing materials.	Capacity per minute.	Height of water above (+) or below (—) surface.	Depth of casing.	Physical characteristics.
				Meters.		*Inches.*		*Liters.*	*Meters.*	*Meters.*	
98	118478	620	Oriental Negros, Dumaguete (Silliman Institute).	13	do		Sand, andesite	F 1135		7	
99	118820	621	Oriental Negros, Bacong	150	June		Pumiceous sand and gravel.	P 264		149	Red sediment.
100	119102	621	do	150	August		do	P 94		149	Normal.
101	119090	654	Oriental Negros, Dauin	68	July		Andesite, coral, and tuff	P 75		65	Turbid.
102	119409	676	Oriental Negros, Zamboanguita.	42			Andesite	P 302		42	Normal.
103	119337		Pampanga, Lubao		October						Yellow.
104	118044	535	Pangasinan, Asingan	171	December			P 378		93	Normal.
105	118045	558	Pangasinan, Rosales	182	do	4.5	Gravel ?	P 378	—27.4	107	Do.
106	118950	602	do	221	June	4.5	Gravel	P 227		220	
107	119079	602	do	221	August						Do.
108	118174	598	Pangasinan, Urdaneta	79	January	8	Sand and gravel	F 94		77	
109	118300	605	do	85	February	4.5	do	F 56		84	Do.
110	118411	614	Pangasinan, Mabini, Urdaneta.	73	March	6	do	F 340		71	
111	118617	630	Pangasinan, Villasis	34	April	8		F 75		31	
112	118746	637	do	42	May		Clay sand, volcanic	F 265		40	
113	118812	642	Pangasinan, Villasis (barrio San Blas).	31	June	6	Sand	F 189		30	
114	118895	645	Pangasinan, Villasis	73	do	4.5	Sand and gravel	P 227		72	
115	119057	645	do	73				P 227		72	Do.
116	119437	655	Pangasinan, Balungao	229	November		Sand, clay, and tuff	P 37		229	Do.
117	118100	PB	Rizal, San Juan del Monte		January						Do.
118	118695	PB	do		May						

119	118696	PB	do		do						
120	118571	258	Rizal, San Pedro Macati	171	April		Tuff and clay	F 11; P 75		104	
121	119054	438	Rizal, Pasay	117	July	4.5	Sand	F 68		39	Do.
122	119118	520	Rizal, Jalajala	128	August		Tuff etc	P 75		119	Very turbid.
123	1190230	520	do	149	September		do	P 227	— 6.1	148	Brown.
124	119334	520	do	185	October		do	P 56		163	Turbid.
125	119573	701	do	39	December	6		P 113			Do.
126	119614	546	Rizal, Cardona	32	do		Clay, gravel, sand	P 113		20	
127	118141	595	Rizal, Navotas	189	January	6	Tuff, clay, sand	F 47		181	
128	118381	609	Rizal, Tangos, Navotas	198	March		Tuff etc	P 113		175	
129	118456	609	do	214	do		do	P 227			
130	118477	612	Rizal, Taytay	73	do		do	P 132		48	
131	118544	626	do	30	April		Sand, gravel, clay, tuff	P 132		15	
132	118610	632	do	41	do	6	Sand and gravel	P 75		26	
133	118707	639	do	33	May	6	Clay and gravel	P 132		26	
134	118666	627	Rizal, Malabon	143	do		Clay ?	F 1.5; P 113		113	
135	118863	649	Rizal, Malabon (barrio Baritan).	148	June	6	Sand	P 113		143	
136	119028	665	Rizal, Malabon (barrio Tanyong).	88	July		Sandstone	P 113		82	
137	119122	675	Rizal, Malabon (barrio Tansuya).	104	August			P 113		92	Normal.
138	118055		Rizal, Caloocan		January						Do.
139	118499	105	do	217	April		Tuff and sand	F 75			
140	119335	683	do	205	October	4.5	Sand	F 4; P 75		204	Do.
141	119548	695	do	190	December		do	F 94		182	Do.
142	118476	491	Sorsogon, Bacon	174	March			P 113			
143	118526	593	Sorsogon, Juban	160	March	6	Igneous sand	P 45		159	
144	118992	618	do	149	July		Volcanic fragments	P 30		146	
145	119203	668	Sorsogon, Magallanes	122	September		Tuff, volcanic sands, and limestone.	P 113		122	Do.
146	119498	692	Sorsogon, Bulan	114	November		Tuff, with limestone at bottom.	F 19		106	Turbid.
147	119575	699	Zambales, Botolan	116	December			P 75	— 3	76	Do.

TABLE III.—*Analyses of water from deep wells, 1914*—Continued.

Tracing No.	Total solids.	Fixed solids.	Volatile solids.	Free ammonia.	Albuminoid ammonia.	Nitrates.	Nitrites.	Chlorine (Cl).	Carbonates (CO_3).	Bicarbonates (HCO_3).	Sulphates (SO_3).	Alkalinity ($CaCO_3$).	Silica (SiO_2).	Iron oxide and alumina ($Fe_2O_3+Al_2O_3$).	Iron (Fe).	Calcium (CaO).	Magnesium (MgO).	Total hardness ($CaCO_3$).	Analyst.
1	228			0.012	0.067	0.099	0.0	2.44			8.8		21.7	1.7		23.7	10.7		Natividad.
2	174	114	60	0.004	0.041	(d)	0.8	1.9			0.5		73.7	15.7		19.7	18.7		Do.
3	1,565.5							567.0	0.0	145.2	[a]43.5	119.0	30.0		(d)	[b]35.7	[c]6.3	107.9	Peña.
4	206			0.348	0.097	0.0	0.0	5.71			(d)		65.7	4.9		(d)	(d)		Gana and Natividad.
5	208			0.202	0.144	(d)	0.0	6.2			73.3		59.7	3.7		1.7	0.0		Natividad.
6	420			0.035	0.042	0.0	(d)	7.6											Do.
7	670			0.048	0.012	0.0	0.0	191.1			37.0		25.7	1.7		51.7	49.8		Do.
8	562	476	86	0.004	0.019	(d)	0.0	130.3			19.7		21.7	1.7		89.7	52.0		Do.
9	294	270	24	0.019	0.024	(d)	1.2	4.3			76.7		85.7	7.7		43.7	5.7		Do.
10	328.8			0.005	0.038	0.0	-(d)	4.68			7.7		58.9	1.7		59.7	27.6		Gana.
11	380.0			0.007	0.0	(d)	(d)	10.3			6.1		73.7	3.7		49.7	28.9		Natividad.
12	390.0	340	50	0.021	0.009	0.0	0.0	9.2			9.5		77.7	3.7		39.7	30.3		Do.
13	355.7	287.6	68.1	0.0	(d)	0.63	(d)	11.5			6.0		67.7	3.7		55.7	23.1		Do.
14	376	314	62	0.0	0.0	0.0	(d)	9.9			6.0		67.7	(d)		21.3	24.5		Do.
15	370.0							6.3	0	189.7	[a]42.9	272	6.5		(d)	[b]42.9	[c]16.2	155.0	Peña.
16	362.5							7.2	0.0	278.7	[a]4.1	253	57.5		(d)	[b]48.3	[c]19.1	199.8	Do.
17	382			0.009	0.0	2.37	0.06	13.0			23.7		71.7	9.7		71.7	59.7		Natividad.
18	382			0.019	0.009	1.18	(d)	14.8			5.3		69.7	1.7		67.7	27.4		Do.
19	390	324	66	0.007	0.009	4.9	(d)	13.0			86.7		75.7	7.7		69.7	18.7		Do.
20	864			1.09	0.03	(d)	(d)	155.7			0.0		31.7	3.7		1.7	2.0		Do.
21	980	940	40	0.898	0.033	0.0	0.0	247.6			10.1		37.7	3.7		25.7	18.7		Do.
22	825.0							108.2	0.0	646.6	[a]0.0	551.0	32.5		2.5	[b]10.2	[c]0.0	26.8	Peña.
23	802.0			0.294	0.211	0.0	(d)	18.2			129.5		29.7	4.9		194.5	120.9		Gana and Natividad.
24	240			0.024	0.014	(d)	(d)	3.26			22.5		97.7	7.7		31.7	10.0		Do.
25	418			0.398	0.301	(d)	0.0	42.2			6.0		13.7	1.3		132.1	7.8		Natividad.

26				0.060	0.048	(d)	0.0	17.2	8.6	161.7	15.4		29.6	0.75		3.7	(d)		Gana.
27	588.6			0.137	0.063	0.0	0.0	278.3			11.4		18.1	3.3		17.3	(d)		Do.
28	968.0			0.280	0.068	0.0	0.0	542.4			4.0		17.72	7.7		29.7	1.4		Do.
29	1,089.6			0.38	0.06	0.0	0.0	584.8			107.6		17.7	1.7		45.7	0.6		Natividad.
30	295.6			0.361	0.140	0.0	(d)	10.8											Gana.
31	290.0			0.145	0.101	0.0	(d)	12.8											Do.
32	290.0			0.188	0.113	0.0	0.0	14.3											Do.
33	278.0			0.164	0.130	(d)	(d)	12.8											Do.
34	264.0			0.034	0.063	(d)	(d)	3.4											Do.
35	260.0			0.048	0.048	0.0	0.0	3.4											Do.
36	235.0							6.2	0.0	161.0	(ad)	132.0	90.0		(d)	[b]25.0	[c]10.8	89.2	Peña.
37	235.0							8.2	0.0	167.1	(ad)	137.0	85.0		(d)	[b]25.0	[c]10.8	89.2	Do.
38	235.0							6.2	0.0	164.5	(ad)	143.0	90.0		(d)	[b]22.0	[c]10.8	80.5	Do.
39	235.0							6.2	0.0	161.0	(ad)	132.0	90.0		(d)	[b]22.0	[c]12.0	83.6	Do.
40	1,513.6			4.8	0.4	(d)	0.0	628.1			415.6		59.7	3.7		55.7	112.8		Natividad.
41	384			0.103	0.004	(d)	(d)	18.4			8.8		93.7	1.7		11.7	5.4		Do.
42	896	314	82	0.033	0.012	0.0	0.0	9.2			10.1		77.7	11.7		53.7	20.8		Do.
43	350.0							29.0	0.0	250.1	[a]16.5	205.0	67.0		(d)	[b]24.6	[c]2.2	70.5	Peña.
44	436.0			0.166	(d)	0.0	0.0	16.84			36.26		75.72	1.72		31.72	15.1		Natividad.
45	456.0			0.195	0.021	0.0	0.0	19.4			4.7		83.7	3.7		27.7	17.9		Do.
46	482.0			0.067	0.024	0.0	0.0	22.8			26.2		75.7	1.7		7.7	1.2		Do.
47	428.0			0.096	0.048	0.0	(d)	10.34			(d)		79.7	3.7		44.1			Gana.
48	438.0			0.130	0.014	0.0	0.0	11.95			18.4		87.7	0.5		35.7	13.4		Natividad.
49	22			0.101	0.036	0.0	0.0	12.9			8.8		83.7	0.1		29.3	4.9		Do.
50	3,834			0.053	0.486	(d)	0.01	2,155.1			1.9		3.7	15.7		249.7	126.5		Do.
51	510							39.9	0.0	237.9	[a]5.2	195.0	28.0		(d)	[b]71.5	[c]18.4	232.8	Peña.
52	466.0			0.010	0.169	0.0	(d)	38.04			17.0		47.7	2.5		86.9	32.5		Gana.
53	1,650	1,428	222	0.024	0.036	1.6	0.03	619.0			67.8		9.7	3.7		201.7	73.0		Natividad.
54	804	732	72	0.036	0.012	(d)	(d)	157.4			39.0		43.7	1.7		141.7	28.1		Do.
55	2,233.6			8.933	0.471	(d)	(d)	354.7			(d)		53.7	1.7		179.7			Gana.
56	2,340.0			8.162	0.737	0.0	0.0	875.4			(d)		61.3	10.1		163.7	96.5		Do.
57	1,132	1,084	48	5.792	0.435	(d)	0.0	245.4			1.9		25.7	7.7		5.7	0.6		Natividad.
58	254.8			0.070	0.046	(d)	(d)	5.41					75.7	1.7		43.3			Gana.

[a] In terms of SO_4. [b] In terms of Ca. [c] In terms of Mg. [d] Traces.

TABLE III.—*Analyses of water from deep wells, 1914*—Continued.

Tracing No.	Total solids.	Fixed solids.	Volatile solids.	Free ammonia.	Albuminoid ammonia.	Nitrates.	Nitrites.	Chlorine (Cl).	Carbonates (CO_3).	Bicarbonates (HCO_3).	Sulphates (SO_3).	Alkalinity ($CaCO_3$).	Silica (SiO_2).	Iron oxide and alumina ($Fe_2O_3+Al_2O_3$).	Iron (Fe).	Calcium (CaO).	Magnesium (MgO).	Total hardness ($CaCO_3$).	Analyst.
59	518			0.122	0.072	(d)	0.0	59.7			1.3		81.7	0.5		17.9	3.5		Natividad.
60	1,306	1,138	168	1.026	0.072	0.0	0.0	282.8			297.6		37.7	15.7		85.7	44.0		Do.
61	742.0	676	66	0.265	0.048	0.0	(d)	173.7			55.3		72.0	(d)		14.0	26.4		Gana.
62	240			0.022	0.010	(d)	(d)	5.4			11.5		39.7	3.7		71.7	14.3		Gana and Peña.
63	1,636			10.3	0.615	(d)	0.0	352.9			5.4		33.7	9.7		11.7	17.3		Natividad.
64	1,356	1,288	68	5.928	0.458	(d)	0.0	249.7			12.2		45.7	9.7		5.7	12.2		Do.
65	626	606	20	0.132	(d)	0.0	0.0	157.4			17.0		65.7	1.7		9.7	3.5		Do.
66	690			0.079	0.004	(d)	0.0	147.2											Do.
67	552			0.091	0.007	(d)	0.0	33.9			1.7		65.7	1.7		13.7	1.7		Do.
68	536			0.089	0.016	0.0	(d)	30.4			3.3		61.7	(d)		7.7	(d)		Do.
69	1,292			0.201	0.086	(d)	0.0	603.7			506.1		43.7	5.7		47.7	19.4		Do.
70	290			0.053	0.038	(d)	0.0	33.6											Do.
71	260			0.070	0.012	0.0	0.0	32.6			21.8		31.7	(d)		1.6	0.0		Do.
72	6	4	2	0.053	0.021	0.0	0.0	1.1											Do.
73	252.5							32.5	0.0	82.9	[a]66.5	68.0	26.0		(d)	[b]1.8	[c]0.0	4.5	Peña.
74	230.0							32.0	0.0	79.3	[a]54.6	65.0	35.0		(d)	[b]1.8	(cd)	4.5	Do.
75	261.0							33.9	0.0	80.5	[a]51.5	66.0	30.0		(d)	[b]1.8	(cd)	4.5	Do.
76	545.0			0.056	0.053	0.0	0.0	134.0			(d)		60.0	7.0		15.0	(d)		Gana.
77	1,275.0							436.8	0.0	563.6	[a]6.0	462.0	10.0		10.0	[b]196.6	[c]32.8	490.6	Peña.
78	488			0.042	0.076	0.59	0.67	30.3			0.0		69.7	21.7		3.7	28.1		Natividad.
79	198			0.067	0.002	0.0	0.0	7.0			0.0		21.7	0.3		5.3	1.7		Do.
80	274.0			0.045	0.009	0.0	0.0	3.2			0.0		3.7	1.7		25.7	4.9		Do.
81	368	344	24	0.031	0.007	0.0	0.0	1.0			7.4		35.7	3.7		41.7	13.6		Do.
82	380.0							8.2	0.0	268.4	[a]1.0	220	45.0		(d)	[b]23.2	[c]5.5	80.6	Peña.
83	200.0							15.5	0.0	70.0	[a]2.1	130	15.0		0.0	[b]5.0	[c]0.0	8.9	Do.

84	159.6			0.314	0.362	0.0	0.0	11.33			5.2		46.5	4.9		23.7	16.3		Gana.
85	364			0.198	0.091	(d)	(d)	43.9			8.1		15.7	1.7		9.7	0.0		Natividad.
86	358	334	24			(d)	0.0	31.7			1.3		13.7	1.7		1.7	0.0		Do.
87	318			0.009	0.088	(d)	(d)	8.96			3.5		101.7	7.7		27.7	15.8		Do.
88	244			0.026	0.041	(d)	0.048	64.9			278.0		103.7	1.7		21.7	12.2		Do.
89	240			0.015	0.044	(d)	0.07	6.4			(d)		121.7	9.7		11.7	0.1		Do.
90	250			0.164	0.036	(d)	0.0	2.97											Do.
91	273			0.012	0.014	(d)	0.0	6.5			25.7		99.7	0.3		27.7	37.3		Do.
92	290			0.250	0.014	(d)	0.0	4.0			1.7		111.7	1.7		27.7	31.7		Do.
93	286			0.077	0.024	(d)	0.30	5.7			1.7		105.7	1.7		6.5	65.7		Do.
94	264	220	44			0.49	0.0	5.4			8.1		87.7	7.7		15.7	9.3		Do.
95	318	264	54			0.139	0.0	3.8			0.0		103.7	23.7		15.7	9.3		Do.
96	360	284	76			(d)	0.0	29.3			24.6		99.7	1.7		29.7	40.4		Do.
97	2,316			0.012	0.016	0.0	0.0	1,034			130.9		21.7	1.7		209.7	154.1		Gana and Natividad.
98	224			0.010	0.022	0.675	(d)	6.89			13.7		103.74	1.7		25.7	6.5		Do.
99	222			0.149	0.021	0.085	0.015	4.61			14.9		102.0	5.7		23.7	10.0		Natividad.
100	250	224	26	0.009	0.004	(d)	0.0	4.3			19.7		103.7	11.6		23.7	7.1		Do.
101	338	324	64	0.014		(d)	(d)	40.2			53.4		99.7	3.7		59.7	14.4		Do.
102	242.5							4.2	0.0	124.4	[a]19.6	102.0	93.5		(d)	[b]22.5	[c]5.4	72.2	Peña.
103	312.0	266	46	1.932	0.495	(d)	0.0	9.7			0.0		77.7	1.7		3.7	1.3		Natividad.
104	272.4			0.007	0.019	0.0	0.0	11.57			63.7		69.7	7.7		58.1	7.0		Gana.
105	316.4			0.050	0.014	0.0	0.0	11.33			5.3		34.1	1.7		77.7	23.1		Do.
106	187			0.012	0.014	(d)	0.12	6.2			0.0		21.7	0.0		1.7	0.0		Natividad.
107	190			0.009	0.014	(d)	0.15	7.3			0.0		17.7	1.7		11.7	11.5		Do.
108	266			0.048	0.063	0.0	0.0	15.3					79.7	3.7		43.3			Gana.
109	265.6			0.053	0.041	0.0	(d)	16.3			28.7		85.3	3.7		41.7	4.2		Do.
110	266			0.082	0.048	0.0	0.0	16.8			25.9		85.2	0.5		41.7	5.6		Gana and Natividad.
111	234			0.12	0.02	0.0	0.0	0.2			13.4		42.8	0.0		49.3	0.1		Natividad.
112	250			0.043	0.024	(d)	0.096	9.74			10.1		39.8	1.7		45.7	39.7		Do.
113	246			0.118	0.024	0.0	0.0	9.7											Do.
114	306			0.065	0.041	0.0	0.0	14.3			65.7		85.7	9.7		43.7	9.7		Natividad.
115	236			0.171	0.009	(d)	0.08	13.6			21.2		41.7	3.7		47.7	8.6		Do.
116	515.0							221.0	0.0	51.9	[a]24.5	42.5	35.0		(d)	[b]21.4	[c]1.2	57.1	Peña.

[a] In terms of SO_4. [b] In terms of Ca. [c] In terms of Mg. [d] Traces.

TABLE III.—*Analyses of water from deep wells, 1914*—Continued.

Tracing No.	Total solids.	Fixed solids.	Volatile solids.	Free ammonia.	Albuminoid ammonia.	Nitrates.	Nitrites.	Chlorine (Cl).	Carbonates (CO_3).	Bicarbonates (HCO_3).	Sulphates (SO_3).	Alkalinity ($CaCO_3$)	Silica (SiO_2).	Iron oxide and alumina ($Fe_2O_3+Al_2O_3$).	Iron (Fe).	Calcium (CaO).	Magnesium (MgO).	Total hardness ($CaCO_3$).	Analyst.
117	228.8			0.046	0.070	0.0	(d)	23.1	0.0	112.2	30.3		20.8	0.8		4.9	0.7		Gana.
118	206.0			0.041	0.026	(d)	0.0	24.9											Natividad.
119	198			0.041	0.019	(d)	0.0	25.4											Do.
120	304			0.024	0.024	0.0	0.0	40			223.4		39.7	0.1		0.3	0.04		Do.
121	1,438			0.113	0.007	0.0	(d)	619			28.0		53.7	5.7		121.7	57.1		Do.
122	1,380	1,168	212	0.381	0.067	(d)	0.0	28.7			407.3		89.7	29.7		253.7	65.0		Do.
123	1,908	1,642	266	0.225	0.001	(d)	(d)	22.8			862.2		113.7	6.9		414.5	76.6		Do.
124	1,134	1,010	124	1.014	0.219	(d)	0.0	49.9			14.9		276.7	29.7		555.7	30.2		Do.
125	1,075							10.0	0.0	408.0	342.0[a]	335.0	97.5		15.0	[b]178.8	[c]28.5	436.5	Peña.
126	765.0							103.0	0.0	274.0	[a]65.9	225.0	130.0		1.0	[b]71.5	[c]22.9	273.0	Do.
127	403.6			0.034	0.055	high	(d	119.7					46.5	1.7		14.9			Gana.
128	1,422			0.077	0.0192	(d)	0.029	637.0			103.4		49.7	1.7		81.7	78.6		Gana and Natividad.
129	710.0			0.096	0.039	(d)	0.0	332.6			36.3		21.7	3.8		37.7	32.5		Do.
130	278			0.118	0.043	(d)	0.0	6.52			(d)		45.7	3.7		25.7	2.8		Do.
131	460			0.007	0.076	0.0	0.0	10.8			14.9		87.7	0.1		81.3	31.3		Natividad.
132	658			0.12	0.08	3.97	0.0	72.5			71.1		95.7	9.7		77.7	0.4		Do.
133	368			0.028	0.014	(d)	0.0	14.0			2.6		87.7	1.7		13.7	8.5		Do.
134	268			0.061	0.091	(d)	(d)	54.1											Do.
135	432			0	0.007	0.0	0.0	139			61.7		39.7	3.7		7.7	9.7		Do.
136	370			0.043	0.033	0.0	0.0	45.6											Do.
137	336	310	26	0.041	0.0	(d)	(d)	17.9			5.4		67.7	3.7		5.7	0.6		Do.
138				0.054	0.052	0.0	0.0	10.34	12.0	247.2	23.9		39.8	8.6		4.4	(d)		Gana.
139	318			0.064	0.023	0.0	0.0	11.95			17.0		38.7	0.1		1.3	6		Natividad.
140	303	290	13	0.041	(d)	0.0	0.0	16.8			1.9		45.7	0.0		(d)	(d)		Do.
141	325.0							13.0	0.0	170.0	[a]13.2	185.0	20.0		0.0	[b]3.6	[c]1.1	7.5	Peña.

142	1,052	------	------	0.245	0.016	(d)	0.0	381.5	------	------	15.0	------	61.7	0.5	------	34.9	15.2	------	Natividad.
143	676	------	------	0.016	0.132	0.284	(d)	8.69	------	------	0	------	121.7	5.7	------	19.7	2.0	------	Do.
144	380	------	------	0.019	0.014	0.054	(d)	9.7	------	------	0	------	111.7	19.7	------	27.7	10.0	------	Do.
145	1,300	1,198	102	0.007	0.048	(d)	0.28	518.0	------	------	43.1	------	9.7	1.7	------	69.7	53.5	------	Do.
146	1,880	------	------	------	------	------	------	764.0	0.0	301.0	103.8[a]	247.5	67.0	------	2.5	[b]72.5	[c]49.2	326.6	Peña.
147	1,550	------	------	------	------	------	------	478.0	0.0	323.3	[a]57.5	265.0	75.0	------	1.5	[b]180.5	[c]63.2	717.2	Do.

[a] In terms of SO_4. [b] In terms of Ca. [c] In terms of Mg. [d] Traces.

TABLE IV.—*Mineral analyses of Philippine waters, 1914.*

Tracing No.	Laboratory No.	Month.	Locality.	Source.	Total solids.	Nitrates (NO_3).	Nitrites (NO_2).	Oxides of iron and alumina (Fe_2O_3 + Al_2O_3).	Silica (SiO_2).	Sulphates (SO_4).	Carbonates (CO_4).	Bicarbonates (HCO_3).
1	118745	May	Albay, Tivi	Tivi spring	177			7.6	63.0	26.0		
2	118110	January	Bulacan, Marilao	Artesian well		(a)	0	0.75	29.6	15.4	8.6	161.7
3	118761	May	Cebu	Palinpinon spring								
4	117934	January	Ilocos Sur, Danglas	Hot spring	2,113.6	0	5.6	18.6	127.3	965.6	0	21.4
5	118304	February	Manila	City water supply	154	0.203	(a)	1.7	23.7	13.8	0	139.1
6	118570	April	Mindoro, Port Galera	Hot spring				0	79.7	578.9	38.1	976
7	118055	January	Rizal, Caloocan	Artesian well		0	0	8.6	39.8	23.9	12.0	247.2
8	118100	do	Rizal, San Juan del Monte	P. B. artesian well	228.8	0	0	0.8	20.8	30.3	0	112.2

Tracing No.	Phosphoric acid (PO_4).	Boric acid (BO_2).	Arsenic acid (AsO_4).	Chlorine (Cl).	Bromine (Br.)	Iodine (I).	Manganese (Mn).	Calcium (Ca).	Magnesium (Mg).	Potassium (K).	Sodium (Na).	Lithium (Li).	Analyst.
1				4.3				11.2	2.9	8.1	19.3		Natividad.
2	(a)	(a)	0	17.2	0	0	0	3.7	(a)	3.0	78.9	0	Gana.
3				2,577.5									Natividad.
4	13.6			226.6				161.4	6.5	83.5	387.7	0	Gana.
5	(a)			4.07				31.2	6.5	1.9	12.7		Gana and Natividad.
6				518				169.7	217.6	355.1	2,944.7		Natividad.
7	0	(a)	0	10.34				4.4	(a)	4.0	107.8		Gana.
8	(a)			23.15			0	4.9	0.7	(a)	87.0	(a)	Do.

[a] Trace.

TABLE V.—*Analyses of waters from miscellaneous sources in the Philippine Islands.*

Tracing No.	Laboratory No.		Month.	Source.	Physical characteristics.	Total solids.	Free ammonia.	Albuminoid ammonia.
1	118064	Albay, Tivi	January	Hot spring	Odor of H_2S	[a] 128.8	0.022	0.199
2	119022	Bohol, Anda, Ilaya	July	"Fuente de Casiac" Spring		[a] 278	0.019	0.014
3	119338	Cebu	October	Poro Spring	Normal	268	(c)	0.016
4	119339	do	do	Tudela Spring	do	264	(c)	0.009
5	119540	Cebu, Mactan Island	December	Surface well	Turbid	4,215		
6	117934	Ilocos Sur, Danglas	do	Hot spring	Reddish brown color	[a] 2,113.6	4.27	0.616
7	118674	Ilocos Sur, Bantay, barrio Paing	January	Canyau Spring	Normal	173.6	0.034	0.058
8	118260	do	February	do		178.0	0.017	0.072
9	118708	Jolo	May	Taigkasan River		[a] 196.0	0.050	0.082
10	118709	do	do	Sablay Puti River		212.0	0.036	0.057
11	118304	Manila	February	Public water supply	Normal	154.0	0.028	0.116
12	118570	Mindoro, Port Galera	April	Hot spring	Smell of H_2S		11.41	0.25
13	119066	Mindoro, Calapan	August	Spring	Normal	486	0.012	0.014
14	118446	Palawan	March	Underground river	Fishy smell	8,688	0.289	0.152
15	118678	Palawan, Puerto Princesa	May	Excavation		554	0.036	0.041
16	118065	Rizal, San Juan del Monte	January	Surface well	Normal	256.4	0.010	0.055
17	118179	Tayabas, Lucena	do	Macaas River		[a] 144.4	0.036	0.128
18	119406	Tayabas, Guinayangan	November	Maulawin Spring	Normal	334		
19	118655	Zamboanga	May	Tumaga River		208	0.015	0.024

[a] Blackening on ignition.

[c] Trace.

TABLE V.—*Analyses of waters from miscellaneous sources in the Philippine Islands*—Continued.

Tracing No.	Nitrates (N).	Nitrites (N).	Chlorine (Cl).	Carbonates (CO_3).	Bicarbonates (HCO_3).	Sulphates (SO_3).	Alkalinity as $CaCO_3$.	Silica (SiO_2).	Oxides of iron and aluminum (Fe_2O_3+Al_2O_3).	Iron (Fe).	Calcium (CaO).	Magnesium (MgO).	Total hardness ($CaCO_3$).	Analyst.
1	0	0	2.5	----------	----------	20.2	----------	62.5	1.7	----------	11.7	(e)	----------	Gana.
2	0	0	9.2	----------	----------	0	----------	15.7	2.5	----------	122.2	3.5	----------	Natividad.
3	(e)	(e)	13.0	----------	----------	6.1	----------	11.7	0.3	----------	131.3	2.1	----------	Do.
4	0	0	11.9	----------	----------	0.5	----------	17.7	1.7	----------	121.7	1.4	----------	Do.
5	----------	----------	1,936.0	0	262.0	b 201.0	215.0	10.0	----------	(e)	c 353.2	d 149	1,509	Peña.
6	0	1.7	226.6	0	21.4	b 965.6	----------	127.3	18.6	----------	c 161.4	d 6.5	----------	Gana.
7	(e)	0	3.4	----------	----------	5.9	----------	30.5	1.7	----------	48.5	14.5	----------	Do.
8	0	0	3.3	----------	----------	6.1	----------	31.7	0.7	----------	54.9	12.2	----------	Do.
9	(e)	0	5.1	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	Natividad.
10	(e)	0	4.3	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	Do.
11	0.046	(e)	4	0	139.1	b 13.8	----------	23.7	1.7	----------	c 31.2	d 6.5	----------	Gana and Natividad.
12	0	(e)	518.0	38.1	976	b 578.9	----------	79.7	0	----------	c 169.7	d 217.6	----------	Natividad.
13	(e)	0	55.8	----------	----------	5.4	----------	71.7	1.7	----------	121.7	14.4	----------	Do.
14	(e)	0	5,559.0	----------	----------	516.6	----------	23.7	3.7	----------	199.7	521.3	----------	Do.
15	(e)	(e)	51.9	----------	----------	19.7	----------	61.7	1.7	----------	179.7	28.8	----------	Do.
16	(e)	0	7.6	----------	----------	(e)	----------	122.1	4.9	----------	27.7	12.4	----------	Gana.
17	(e)	0	6.4	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	Do.
18	----------	----------	22.1	0	320.9	14.2	263.0	4.0	----------	(e)	c 85.9	11.3	252	Peña.
19	0	0	1.6	----------	----------	7.4	----------	23.7	11.7	----------	45.7	7.8	----------	Natividad.

b In terms of SO_4. c In terms of Ca. d In terms of Mg. e Trace.

TABLE VI.—*Field assays of waters from deep wells in the Philippine Islands.*

Tracing No.	Laboratory No.	Location.	Artesian well No.	Depth.	Flows or pumps liters per minute.	Temperature.	Alkalinity ($CaCO_3$)	Iron (Fe).	Sulphates (SO_3).	Chloride (Cl).	Carbonates (Na_2CO_3).	Bicarbonates ($CaCO_3$).	Total hardness ($CaCO_3$).
				Meters.									
1	54	Cebu, Argao, on plaza in front of municipio.			Pumps [a]	28.5	20.0	2.0	43.5	140.7	0	20.0	120.0
2	45	Cebu, Cauit Island		82	do [a]		70.0			8,200.0	0	70.0	220.0
3	63	Cebu, Carcar; Philippine Railroad Co			do		40.0		(b)	29.0	0	40.0	276.0
4	65	Cebu, Carcar; Santa Catalina			do		31.0		26.0	40.0	0	31.0	200.0
5	18	Cebu, Cebu; customhouse			Pumps 227 liters		57.0		(b)	111.0	0	57.0	66.0
6	19	Cebu, Cebu; at carbon public market			Pumps		140.0		(b)	27.5	0	140.0	122.0
7	22	Cebu, Cebu; Bagumbayan		27.5		29			(b)			27.5	
8	23	Cebu, Cebu; Calles Lapulapu and Manalili.			Pumps	29.5	66.6	2.0	82.0	89.0	35.3	33.3	68.0
9	44	Cebu, Cebu; next to 114 Juan Luna			do		60.0			19.4	0	60.0	262.0
10	29	Cebu, Toledo	689	55	do		68.5	4.5	18.0	124.0	0	68.5	244.0
11	73	Iloilo, Iloilo; Plaza Libertad	[d] 511	63	Flows [a]		72.5	4.0	0	870.0	0	72.5	370.0
12	75	Iloilo, Iloilo; Landon mess	[d] 523	65	Pumps	40	35.0	2.0	0	1,060.0	0	35.0	442.0
13	76	Iloilo, Iloilo; Calles Lanao and Yznart	[d] 592	80	Flows 16 liters	29	51.0	2.0	0	930.0	0	51.0	240.0
14	77	Iloilo, Iloilo; Convent Assumption Sisters.	428	78	Flows 18 liters	29	31.0	4.0	0	790.0	0	31.0	234.0
15	66	Iloilo, Iloilo; Molo	480	91	Flows 3 liters	28.7	89.5	2.2	0	376.0	0	89.5	230.0
16	67	do	580	55	Flows 37 liters		72.5	1.0	(b)	600.0	0	72.5	400.0
17	100	Iloilo, Janiuay; at plaza			Flows	28.5	51.7	(c)	0	12,155.0	0	51.7	274.0
18	71	Iloilo, Jaro; at plaza			do	30	58.0	(c)	0	1,430.0	61.5	0	46.0
19	70	Iloilo, Mandurriao; Calles R. Papa and Cementerio.	490	87	Pumps 113 liters	28.7	37.5	2.5	0	318.0	34.8	12.5	58.0
20	102	Iloilo, Santa Barbara; on plaza		152	Flows 28 liters	29	75.0	(c)	0	242.0	60.5	17.5	17.0
21	3	Mindoro, Calapan; at public market		24		40	440.0	10.0		1,040.0	0	440.0	

[a] Slight flow at high tide. [b] Trace. [c] High. [d] All Iloilo deep-well waters are yellow.

TABLE VI.—*Field assays of waters from deep wells in the Philippine Islands*—Continued.

Tracing No.	Laboratory No.	Location.	Artesian well No.	Depth.	Flows or pumps liters per minute.	Temperature.	Alkalinity. ($CaCO_3$)	Iron (Fe).	Sulphates (SO_3).	Chloride (Cl).	Carbonates. (Na_2CO_3).	Bicarbonates ($CaCO_3$).	Total hardness ($CaCO_3$).
				Meters.									
22	11	Mindoro, Naujan; at presidencia		54	Flows 18 liters	30	44.0		10		24.0	22.0	low
23	12	Mindoro, Naujan; 100 meters west of presidencia.		55	Flows		57.0				30.0	28.5	
24	13	Mindoro, Naujan; near seashore		67	do		50.0				21.0	30.0	
25	10	Mindoro, Pinamalayan; new townsite		54	do		20.0	(b)	22		0	20.0	60.0
26	8	Mindoro, Pola; near presidencia		6	Pumps		160.0				0	160.0	174.0

[b] Trace.

TABLE VII.—*Field assays of spring waters in the Philippine Islands.*

Tracing No.	Laboratory No.	Location.	Source.	Temperature.	Alkalinity ($CaCO_3$).	Iron (Fe).	Sulphates (SO_3).	Chlorides (Cl).	Carbonates (Na_2CO_3).	Bicarbonates ($CaCO_3$).	Total hardness ($CaCO_3$).
				°C.							
1	111	Capiz, Capiz; near railroad terminal	Spring and pool		46.8	0.35	125.0	85.0	0	46.8	106.0
2	56	Cebu, Argao	Kabagohan Spring		33.4		(a)	5.5	0	33.4	318.0
3	35	Cebu, Asturias; southeast of town; 1 kilometer from municipio.	Spring		50.0	1.4	(a)	16.5	0	50.0	180.0
4	34	Cebu, Balamban; barrio Cambojaue	Spring		30.8	(?)0.5	(a)	77.0	0	30.8	230.0
5	61	Cebu, Carcar	Guadalupe Spring	26.5	30.8	0.5	(a)	11.0	0	30.8	214.0
6	21	Cebu, Cebu; beach near leper hospital	Springs	30		2.0	(a)	148.5	0		
7	47	Cebu, Minglanilla; about 200 meters northeast of schoolhouse.	do		53.0	0.5	(a)	14.0	0	53.0	200.0
8	48	Cebu, Naga	Jugan Spring	29	49.0	0.3 -	32.0	142.0	0	49.0	232.0
9	58	Cebu, Sibonga	Spring		33.4	(a)	(a)	37.0	0	33.4	222.0
10	104	Iloilo, Santa Barbara; at golf club	do		66.7		(a)	8.0	0	66.7	131.0
11	1	Mindoro, Calapan; 4 kilometers back of town	do	30	405.0	0.25		55.0	0	405.0	420.0

[a] Trace.

TABLE VIII.—*Field assays of surface waters in the Philippine Islands.*

Tracing No.	Laboratory No.	Location.	Source.	Depth.	Temperature.	Color.	Turbidity (SiO_2).	Alkalinity ($CaCO_3$).	Iron (Fe).	Sulphates (SO_3).	Chlorides (Cl).	Carbonates (Na_2CO_3).	Bicarbonates ($CaCO_3$).	Total hardness ($CaCO_3$).
				Meters.	°*C.*									
1	42	Capiz, Capiz; in front of church	Surface well	2		0	0	53.5	0.13	46.0	95.0	0	53.5	180.0
2	114	Capiz, Dao	Concrete sump			100	(a)	33.4	2.7	0	8.0	0	33.4	66.0
3	117	Capiz, Dumarao; south of town	Sump			25	(a)	50.0	1.5	27.5	11.5	0	50.0	152.0
4	52	Cebu, Argao; at market place	Surface well	1.5		0	0	50.0		35.0	44.5	0	50.0	282.0
5	53	Cebu, Argao; at convent	do	1.5	28	0	0	54.5			82.5	0	54.5	334.0
6	55	Cebu, Argao; at municipal building	do					33.4			109.0	0	33.4	318.0
7	36	Cebu, Balamban; about 2 kilometers from Balamban, road to Asturias.	Combado River			0	(a)	34.6	1.4	(a)	7.0	0	34.6	186.0
8	37	Cebu, Balamban; on plaza	Surface well	3		0	(a)	51.0	1.0	(a)	88.5	0	51.0	232.0
9	62	Cebu, Carcar; Calle San Jose	do					33.4			42.0	0	33.4	294.0
10	64	Cebu, Carcar; No. 22 Calle S. Vicente.	do					33.4		23.0	23.0	0	33.4	342.0
11	16	Cebu, Cebu; Buhisan	Osmeña Waterworks		31	0	0	50.0	2.6	67.0	6.0	0	50.0	202.0
12	17	Cebu, Cebu; No. 57 Calle Colon	Surface well	5	27.5	0	0	77.0	1.4	(a)	25.0	0	77.0	100.0
13	20	Cebu, Cebu; near the Southern Island Hospital.	do		29	0	95.0	50.0	1.0	(a)	13.5	0	50.0	256.0
14	40	Cebu, Cebu; No. 193 Colon	do	4				47.0			51.5	0	47.0	268.0
15	41	Cebu, Cebu; No. 114 Juan Luna	do	2				70.5			203.0	0	70.5	454.0
16	42	Cebu, Cebu; Calles Manalili and N. America.	do	2.5				45.0			25.5	0	45.0	220.0
17	46	Cebu, Minglanilla; near market	do	9		0	0	51.0	3.4	(a)	41.0	0	51.0	258.0
18	49	Cebu, Naga; Calles Rizal and Buencamino.	do	2		0	0	54.5	0.3	129.0	254.0	0	54.5	358.0
19	50	Cebu, Naga; at convent	do					50.0		76.0	254.0	0	50.0	266.0
20	51	Cebu, Naga; on provincial road	do	2.5				54.5			144.0	0	54.5	232.0
21	57	Cebu, Sibonga; No. 1 Calle Burgos	do					51.0			320.0	0	51.0	454.0
22	59	Cebu, Sibonga; Saba	do	1							16.5			

23	60	Cebu, Sibonga; near municipio	do								156.0			200.0
24	28	Cebu, Toledo; on plaza opposite municipio.	do	4		0	(a)	49.0	(a)	(a)	148.0	0	49.0	300.0
25	30	Cebu, Toledo	Grande Subak River	1		0	80.0	50.0	5.0	125.0	13.5	0	50.0	220.0
26	31	Cebu, Toledo; Espeleta	Surface well	1		0	(a)	60.0	2.5	(a)	35.5	0	60.0	322.5
27	32	Cebu, Toledo; Calle Fermin Polayapoy.	do	6		0	0	50.0			111.0	0	50.0	368.0
28	33	Cebu, Toledo; Calle Adriano Blanco	do		29	0	0	47.5			68.0	0	47.5	344.0
29	69	Iloilo, Iloilo; Plaza Libertad	do	2			0	54.5	1.0	350.0	790.0	0	54.5	440.0
30	87	Iloilo, Iloilo; at Army post	do	6		0	113.0	44.5	(b)	600.0	8,150.0	26.5	19.4	820.0
31	88	Iloilo, Iloilo; at the Trade School	do	6	?27	0	0	50.0	0	11.0	71.0	0	50.0	212.0
32	89	Iloilo, Iloilo; near Assumption College.	do	3		100.0	0	52.5	1.0	500.0	805.0	31.6	19.7	52.0
33	105	Iloilo, Iloilo; Molo, Calle Antigua No. 2.	do	1		0	0	62.5		(b)	480.0	0	62.7	394.0
34	106	Iloilo, Iloilo; Calles Ortiz and J. M. Basa.	do	2		0	0	54.5		53.0	57.0	0	54.5	192.0
35	107	Iloilo, Pototan; behind Bureau of Public Works automobile shed.	do	2		0	0	51.7	1.3	38.0	42.0	0	51.7	182.0
36	108	Iloilo, Pototan; behind tienda opposite railroad station.	do	4		0	0	50.0	2.3	96.0	27.0	0	50.0	200.0
37	109	Iloilo, Pototan; Calle Jaena, adjacent to municipio.	do	3		0	0	46.0	1.7	73.0	85.0	0	46.0	282.0
38	108	Iloilo, Sta. Barbara; No. 16 Calle Magalona.	do	1.5		0	0	58.7	0.7	73.0	290.0	0	58.7	374.0
39	7	Mindoro, Pola; 50 to 75 meters from beach.	Driven well	5.5		0	0	300.0				0	300.0	369.0
40	9	Mindoro, Pinamalayan; 2.5 kilometers beyond town.	River			0	0		(a)	0		0	60.0	93.0
41	5	Mindoro, Pola	Tiguihan River		27.5	0	(a)		0.1	0		0	60.0	65.0
42	2	Mindoro, Calapan	Surface well	5		0	0				110.0			

[a] Trace.

[b] Very high.

REVIEWS

Cocoa | by | Dr. C. J. J. van Hall | director of the Institute for Plant-Diseases and Cultures, | Buitenzorg, Java | with illustrations and map | Macmillan and Co., Limited | St. Martin's Street, London | 1914 | Cloth, pp. i-xvi+1-515.

The Coco-nut | by | Edwin Bingham Copeland | professor of plant physiology and dean of the | College of Agriculture, University of | the Philippines | Macmillan and Co., Limited | St. Martin's Street, London | 1914 | Cloth, pp. i-xiv+1-212.

The literature of tropical agriculture has been notably enriched by the appearance of these two new works. The development of tropical agriculture during the past twenty-five years has presented many interesting and noteworthy features. It has differed markedly from the development of temperate-region agriculture, and it has been able to borrow comparatively little from the latter. Many of its crops are entirely peculiar to the tropics, and tropical conditions furnish a series of wholly unique problems. Tropical planters have had to feel their way by painful steps, gradually gaining the local experience necessary for successful, practical operations. Even this kind of development has been far more rapid than in the case of temperate region agriculture, largely due to the fact that tropical agriculture has been characterized by the investment of large capital. The capital invested gradually drew to its service well-trained technical men from the temperate countries. In late years the establishment in colonial possessions of active agricultural experimental stations has given a great impetus to the development of the technical side of tropical agriculture. Much of the early literature of tropical agriculture consisted of accounts of the personal experiences in tropical planting of untrained men, some of whom, however, in the school of hard experience finally became very successful planters. Until within the last decade really high-grade technical works on tropical agriculture were very few, and even yet works like Semler's Tropische Agrikultur and Warburg's Die Muskatnuss remain very rare.

There is the same difference between the mass of the earlier literature and these later works as exists between a farm school and a college of agriculture. The methods of the farm school

are those of formula and precept, largely of only local application. The students of the farm school cannot receive the basic scientific training which would enable them either to coördinate or to generalize their results safely, or to understand clearly the reasons back of their practical operations. As Doctor van Hall clearly shows, many of the cacao "experts" of former years commonly failed in this. On the other hand, the college of agriculture requires a thorough preparation in the sciences basic to agriculture, in order that its students may be able to apply more or less sound reasoning to all agricultural phenomena and problems that may present themselves, and also enable them to adapt their practice and learning, on the basis of intelligent ratiocination, to a wide range of natural conditions. The unexpected is the daily diet of the tropical planter.

The two books under consideration well represent the college grade of tropical agricultural science. They are exceedingly rich in the application of modern science to the growing of two very important tropical crops. They probably represent the highest development yet attained in the agronomy of any tropical crop. In a number of otherwise great special works on tropical agriculture this aspect—the art and science of producing the crop—has been seriously neglected, due largely, of course, to the lack of the exact data that can only be obtained by comprehensive and long-continued experimentation. This is characteristic of works on cane, for example, in which the manufacturing side has received the major attention; although, with the highly important results of the past few years, a good preliminary text on the agronomy of cane is now for the first time possible. In a recent very extensive work on cacao only 20 pages are devoted to the entire agronomy-side of the subject. While the two present works represent the latest and most complete results in the agronomy of these crops, still, all through their pages there are encountered references to points and problems yet unsolved. Doctor van Hall's work is particularly valuable in that it includes a critical review, characterized by clear thinking and technical treatment, of all important previous works on cacao. Such an attempt to coördinate and explain the great diversity of former opinion is of the highest possible importance in the development of tropical agriculture. Formerly the planter or student was quite lost in the maze of diverse local opinion, unless, perchance, there happened to exist works relating to operations in his own locality. Doctor van Hall makes available to the student and to the planter the well-digested results from all regions, although he says nothing calculated

to minimize the great importance of local experience. On the contrary, in his preface he remarks: "This does not mean that the intention of the book is to teach the reader cocoa-planting, and it is not expected that anyone unacquainted with cocoa-culture will become a cocoa-planter by reading the book from beginning to end." Again, he remarks very aptly that "often the practical man knows *how* he has to treat his trees or his soil in order to get his best result, but not *why*." He further explains that there are many things which "cannot be learned in the field," and this is a point sometimes lost sight of by some too obstinately "practical" men—men who still harbor the antiquated falsity that any line can be drawn between "science" and "practice."

In Doctor van Hall's full account of the development of cacao culture in many countries one finds of very live interest the description of the peculiar methods of culture in Surinam, and the story of the growth of the industry in the Gold Coast. In the latter country we probably have one of the most remarkable examples in existence of the possible influence of foreigners upon the agricultural development of an essentially primitive people. In 1901, 80 kilograms of cacao were exported from the Gold Coast. In 1911 the country produced more than 40,000,000 kilograms; however, this does not mean the result of investment of large capital, but development of the common people. This evidence of real results in practical colonial agricultural development is one to which we can unfortunately offer no remote parallel in the Philippines, where the people possess a country naturally adapted to cacao, but where they do not yet produce enough to supply their own local needs, and this nearly two hundred fifty years after its successful introduction! A thousand copies, at least, of Doctor van Hall's book should find readers in the Philippines.

Doctor Copeland's book is a splendid example of scholarly and scientific treatment. It is, perhaps, the best case extant in a work on any single major tropical crop of the application of modern biological methods to all the details of the agronomical side of the subject. An innovation in this work, of the highest possible importance, consists of a thorough consideration of the physiology of the coconut tree. There is no doubt but that this will prove an epoch-marking event for the agronomy of all crops and of all countries. We would have little respect for a system of medicine, or confidence in its methods, in which there was no provision for thorough technical study of the

physiology of the human body, yet the agronomy of most tropical and many temperate crops is exactly in this condition—the details of the life operations of the plants in question, as to their foraging ability, food elaboration, water requirements, transpiration habits, organic reaction to surrounding conditions, and specific reaction to disease, being unknown. The experience of the practical planter is one continuous struggle with serious problems, many of which might easily be solved through fuller knowledge of the detailed physiological operations and needs of the plant he is attempting to grow. It seems that if anything is to be expected from real colleges of agriculture as distinguished from farm schools, and more particularly expected from colleges of agriculture in universities, it is a thorough grounding in these basic lines of work that shall enable students to approach the practical problems of agronomy with broad intelligence and really adequate equipment. In this connection Doctor Copeland's book furnishes the best example of what a textbook for a college of tropical agriculture should be. His work is, of course, not final in any respect, and he clearly recognizes, as does Doctor van Hall, that the science of tropical agronomy is an extremely undeveloped one. In the face of this fact some temperate-region agronomists do not seem to be able to understand why things should not be done thus and so in the tropics—along lines well-established in temperate regions. The light will not dawn upon such, or rather the knowledge of the lack of light, until they join the ranks of pioneers in a new tropical country and undertake the practical establishment of well-ordered cacao or coconut plantations. It is evident, for instance, in Doctor Copeland's discussion of fertilizers, that the subject is still an open one, no comprehensive experiments having yet been carried through a sufficiently long term of years. The subject of the seed selection of the coconut still requires thorough investigation and experimentation. Doctor Copeland does not mention the interesting case of the small island of Rotumah in the South Seas, which is said to produce coconuts of unusual size and value. These coconuts, in years past, are said to have been used extensively for the establishment of plantations in other islands, some being reputed to have brought as much as a shilling apiece as seed. It would be a matter of the highest interest and importance to trace the results obtained from these seeds in other islands and under other conditions.

The immediate effect of Doctor Copeland's book will be the stimulation of students, planters, and investigators to more acute

attention to scientific methods in the solving of the very numerous problems in coconut culture. It should be a matter of pride to the University of the Philippines that it has furnished to the world so notable a work of this character.

Many will disagree with Doctor van Hall on the use of the word "cocoa." The original Mexican name of the plant is variously given as "cacahuatl," "cacaguata," or "caquahuitl," and the original Spanish derivative was "cacao." The last form seems to be in very wide use, especially in the Spanish-speaking countries. "Cocoa" is the name commonly applied to the fat-free breakfast powder, and might well be restricted to that application. Nor will everyone agree as to the need of a hyphen in the word "coconut."

In both of these books the treatment of fungous diseases and insect pests is especially complete and practical, and this feature alone would make the appearance of the two works exceedingly opportune. Doctor van Hall's treatment of the subject of cacao varieties is unquestionably far in advance of any yet presented.

The typographical work in both books is admirable, the type being large and clear, and the illustrations—with which both works are replete—being on the whole of exceptionally good quality. The paper used in Doctor van Hall's book is of a much better grade than that in Doctor Copeland's. Both works seem to be remarkably free from typographical errors, the few which do occur rarely confusing the sense, and these few will be corrected in succeeding impressions.

C. F. BAKER.

THE PHILIPPINE

JOURNAL OF SCIENCE

A. CHEMICAL AND GEOLOGICAL SCIENCES
AND THE INDUSTRIES

VOL. X MAY, 1915 No. 3

NOTES ON A GEOLOGIC RECONNAISSANCE OF MOUNTAIN PROVINCE, LUZON, P. I.[1]

By WARREN D. SMITH
(*From the Division of Mines, Bureau of Science, Manila, P. I.*)

FIVE PLATES AND 5 TEXT FIGURES

CONTENTS

INTRODUCTION

The following notes are the result of a geologic reconnaissance made by me during March and April, 1914, in the subprovinces of Bontoc and Kalinga with side excursions of less importance into Lepanto and Ifugao.

The rugged nature of the country, the lack of any trained assistants, and the semiwild character of the people combined to prevent the execution of any detailed or accurate work at this time. Primary triangulation is just now being carried out for the first

[1] Received for publication November 27, 1914.

time, so accurate base maps are wholly lacking. The object of this trip was to traverse as much territory as possible and note the more obvious things of interest first; therefore the following pages will necessarily give fragmentary discussions of the geology of this large area.

FIELD ITINERARY

The route traveled was as follows: Tagudin via Cervantes to Bontoc, Bontoc to Barlig, Barlig to the summit of Mount Amuyao, Barlig to Natonin (southern Kalinga), Natonin to Tabuk, Tabuk to Lubuagan, Lubuagan to Bontoc, Bontoc to Mainit, Bontoc to Lubuagan, Lubuagan to Belotoc, Lubuagan to Balinsogao, Lubuagan to Balbalasan, Balbalasan down the Saltan Valley to Patician, thence to Lubuagan. From here back to Bontoc and on to Sagada, Sagada to Fidelisan and Basao, Sagada to Cervantes and thence to Mancayan, Mancayan to Baguio, and from there to Manila (fig. 1).

Acknowledgments for much assistance in an official capacity and many personal courtesies are hereby made particularly to Gov. E. A. Eckman, of Mountain Province; to Lieut. Gov. Walter Hale, of Kalinga; to Capt. W. E. Moore, senior inspector of Constabulary at Bontoc; and to Lieut. J. F. Oliver, Philippine Constabulary, formerly stationed at Lubuagan. Governor Eckman and Captain Moore accompanied me on my trip through eastern Kalinga, while Lieutenant Oliver accompanied me on several short trips in western Kalinga.

PAST WORK

As far as is known from the literature on the subject, von Drasche is the only geologist who has heretofore gone into the interior of north-central Luzon north of the town of Cervantes, and he traveled only a short distance north of Bontoc and did not go any farther east than Bontoc. He has devoted a chapter in his "Fragmente" to this part of his travels.[2]

As this publication is not easily available, a translation of Chapter VII, which was made for me by Mr. A. E. W. King, Bureau of Science, is inserted here.

THE MILITARY DISTRICTS OF LEPANTO AND BONTOC

The watershed between the large rivers Abra and Agno is only a low chain of hills, consisting of three parallel ranges, having a south-southwesterly direction, and consisting of a weathered sanidine-hornblende-trachyte. Without passing through [the village of] Lipatan, one reaches the hamlet of Mancayan at an elevation of approximately 3,500 feet, which

[2] Fragmente zu einer Geologie der Insel Luzon. Wien (1878), 36–46.

gives a bird's-eye view of the broad valley of the Abra. The formation along the ascent is always a friable trachyte. Toward the east lies the lofty Data, covered with thick forests of oak trees; according to C. Semper this mountain is "an extinct volcano fallen to ruin." There is supposed to be a small lake at the summit. Formerly Mancayan was the scene of

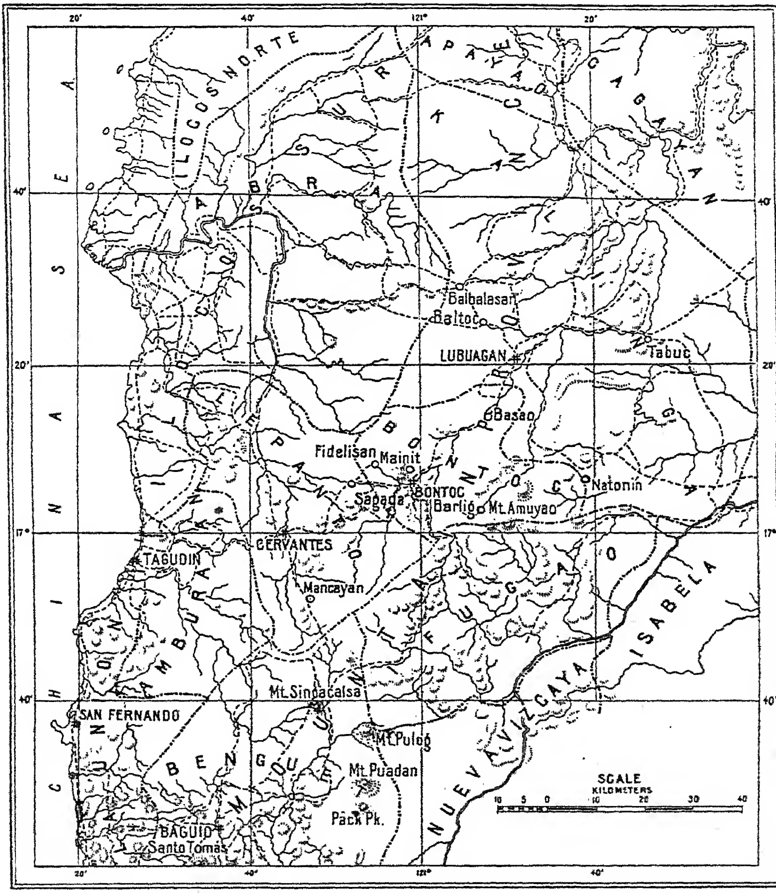


FIG. 1. Outline of northern Luzon, showing region traversed.

extended copper mining, which, however, at present has almost entirely ceased. The ores were already known to the Igorots and were worked by them before the coming of the Spaniards. The courtesy of two Spaniards, who were kind enough to clear away the old rubbish heaps [tailings and gangue] made it possible to obtain an idea of the occurrence of the ores; I also went through several of the galleries myself. The copper minerals occur in a quartz lens found in the sanidine-trachyte, which lens as a whole

appears to have an east and west extension. In this ore body the ore occurs in veins that likewise follow an east-west direction, so that all galleries having a north-south direction expose all the seams. These veins at places are supposed to be 7 meters in width and are uniformly steeply inclined. The distance between these very regular veins, in general, is very little. The ore minerals are principally luzonite, enargite, and covellite, the first-named occurring abundantly in beautiful crystals; besides, I noticed baryte, calcite, copper sulphide, malachite, copper sulphate stalactites, arsenic, and a *saponitartiges* mineral stained blue by copper salts.

Limestone is used in smelting the ores, which is quarried at Mount Malaya, in the cordillera west of Mancayan; judging from the pieces which I saw, it is a coralline limestone. Much gold is said to be panned [washed] south of Mancayan in the mountains of Suyoc and Tubuc, and I was informed also of the occurrence there of hills of gypsum containing crystals of iron-pyrites. According to this information it appears that a part of that extraordinarily serrated mountain chain, which, according to Peñarubio's map continues in the shape of an arch from Suyoc to Pico Tila and then turns directly north, consists of coralline limestone. The northern continuation is, as we shall see, formed almost entirely of this stone.

I continued my journey from Mancayan to Cayan, the capital of the district of Lepanto. One descends the heights, consisting of sanidine-hornblende-trachyte, and very soon reaches again a narrow belt of the Agno beds. Before crossing over to the left bank of Abra River, one encounters large bowlders of an excellent rhyolitic quartz-trachyte. It is noteworthy because of its beautiful flow structure. It is possible to differentiate a quartz-trachyte with a dark gray groundmass and another variety with a red groundmass. Both coalesce in varied *Schlieren*, as Dr. Reyer would say.

In this dense, hard, splintery groundmass there are found closely packed, numberless water-white splinters of quartz. These are never rounded, nor do they show the least trace of regular structure, but are always characterized by their fragmental nature; at times they attain a diameter of 4 millimeters. It is interesting to note that the gray Schlieren only contain nests of pyrite. Thin sections of the rock give no information whatsoever concerning the nature of the groundmass. It is very apparent to the eye that the quartz fragments were not formed out of the groundmass; on the contrary, it is apparent that they were enveloped by the magma which formed the groundmass. I regret that I did not succeed in discovering this interesting trachyte, which certainly has an extraordinarily high silicic acid content, in place, although very large blocks of it are found in the river bed of the Abra. As was indicated on page 36 the copper lodes of Mancayan are found to occur in a quartz lens. There are also found with the quartz-trachyte bowlders a great many fragments of a crystalline quartz, which are stained red in places and marked along fracture planes with iron. It might be appropriate to give an explanation of the origin of this remarkable trachyte.

If a dike of the rhyolite broke through one of the quartz lenses, it is very possible that on its borders there would be formed similar breccialike rocks.

The banks of the Abra are composed of an exceedingly coarse, dolerite breccia; the fragments, somewhat rounded and about the size of a clenched

hand, are cemented together by an earthy binding material. These pieces protrude from the matrix in groups showing no regularity whatsoever. The steep left banks of the Abra very soon disclose a complex of rocks which clearly show stratification and which have a steep inclination toward the north; they are the well-known plagioclase-hornblende-chlorite rocks, which, alternating with white feldspathic strata full of pyrite, make up the Agno beds.

We finally left the bed of the Abra and went eastward over steep mountains with numerous chasms and cliffs toward Pilipit, and from there to Cayan. The entire region is composed of friable, yellow tuffs, that are mostly stratified horizontally. Numerous creeks flow across these tuffs, engorging themselves in the soft rock; the wearisome trail runs up and down directly across their courses.

Before reaching Pilipit, one has a splendid view of Abra Valley, which spreads into a wide hilly plain a short distance beyond the point where we had left it. Recently successful experiments have been conducted in planting the coffee shrub on this plain.

Cayan has an elevation of about 4,000 feet upon a small plateau. South of the place is the mountain Data. At the foot of Mount Data there are said to be numerous hot springs; copper ores are likewise found there; perhaps this might indicate a great extension of the quartz lens of Mancayan toward the east.

Mount Data plays a very important part in the orography of Luzon; it is, so to say, the watershed of the three great rivers, the Agno, Abra, and Bontoc.

The sources of the first two rivers have already been described; both flow into the ocean on the west coast. Bontoc River, which has its origin in the eastern part of the Data mountain range, very likely flows into Bangong River; therefore it pertains to the river system of the Rio Grande de Cagayan.

In the vicinity of Cagayan the true Central Cordillera is merely a much dissected plateau; at a point much nearer the coast it continues its north-northeasterly direction; consequently Cagayan really is situated on the watershed between the west coast and the Rio Grande de Cagayan. Coello's map does not take cognizance of this noteworthy fact. On Plate I this cordillera is correctly drawn.

Sabangan, which lies a six-hour walk to the east of Cayan, is one of the most remote toward the east of the rancherias paying Spanish tribute. I made a trip to this place in order to enter from there into Bontoc district that lies to the north. A short distance behind Cayan mighty breccias of doleritic rocks are encountered, then breccias of hornblende-sanidine-trachyte, and farther eastward there appears a breccialike rock bedded in thick layers. The last-named consists of large and small, irregular fragments of limestone and of a badly weathered trachytic rock; there are also disseminated fragments of feldspar and quartzite. This conglomerate alternates with strata of coralline limestone, very similar in every respect to that found in Benguet Province. The strata show an inclination to the southeast of 8°–12°. Farther toward the east there again appear soft, yellowish tuffs, which continue as far as the cuartel at Sabangan. Sabangan lies on an eminence, in the angle formed by Sabangan and Bontoc Rivers.

The large rancheria, viewed from the cuartel, lies deep down on the left

bank of Bontoc River. The view in this narrow valley, with its sides that jut forth groovelike and upon which are built in steep terraces the well-kept rice fields of the Igorots, is truly splendid.

The shortest way to Bontoc is from Sabangan, provided one follows down the river; by this route it is easy to make the journey to Bontoc in from five to six hours.

This trail, if it may so be called, is absolutely impassable at high water, and even at low water must be traveled afoot on account of the extraordinarily large bowlders. We had brought along horses for our trip in Bontoc, but we had to send them back to Sabangan after trying in vain for one hour to get the animals over the high bowlders. The banks of the river in the vicinity of Sabangan consist of a red, completely decomposed trachyte-tuff, which has an appearance of stratification due to gradations of color. All along the river are found enormous fragments of a coarsely crystalline rock, which is made up of quartz, orthoclase, much plagioclase, and a dark green mineral (chlorite ?) crystallizing in small flexible laminæ. Just out from Sabangan I entered upon the road for Bontoc through Sagada, which is passable for horses. To reach the road it is necessary to cross over to the left bank of a small river, Sabangan River, traversing the yellow tuff formation for a short distance, beyond which one encounters a beautiful quartz-trachyte, which is of considerable extent. This rock is dense, white, and hard, with a splintery fracture. In the dense groundmass one can distinguish white sanidine, glistening like glass, a gray, opaque feldspar crystallized in little columns, quartz in irregular grains, and little crystals of augite—certainly a rare mineral combination. Under the microscope the groundmass resolves itself into a maze of colorless and brown crystals, the latter perhaps being augite microliths. The gray feldspars stand out of the matrix in a most remarkable manner; they are separated from the rest of the groundmass by a sharp, dark border. Augite is rather scarce, while magnetite is present in beautiful crystals. All the disseminated minerals are strongly corroded by the groundmass and contain numerous inclusions. Fig. 3 on Plate III shows very beautiful feldspars in the turbid groundmass.

In the vicinity of Anquilen the trail proceeds in a northerly direction high up on the west wall of the valley.

In the middle of the carefully cultivated, terraced rice fields, with their artificial irrigation system, along this small tributary of the Rio Bontoc, nestle the hamlets Sagada, Balugan, and Anquilen, one above the other. One again crosses bedded series of trachyte-breccias, intercalated with yellow tuffs, and dipping in a southwesterly direction.

No doubt they constitute the northerly continuation of the bedded complex noted between Cayan and Sabangan. At Sagada extensive coralline limestone cliffs are again encountered. These may be traced south almost to Balugan and toward the north to Tetenan. From a distance these give one the impression of a large cemetery with numerous gravestones.

These coral cliffs likewise show stratification with clearly discernible thick beds, usually with a southerly inclination of 15°–20°; between the strata I found a thin layer of greenish tuff. Weathered trachyte is encountered between Tetenan and Bontoc. The greenstone base of the Agno-bed series may be seen at two places also, but over limited areas only. Passing eastward, one very soon reaches Bontoc River at a point where a tributary with exceedingly steep banks enters at right angles from the left.

After having twice crossed the river, Bontoc, the capital of the military district bearing the same name, is reached. It is situated on the left bank of the river, and on the opposite bank lies the important rancheria of Samuqui.

The direction of Bontoc River on Peñarubia's map is shown erroneously as east-west, whereas in reality it is north-northeast. The present governor of Bontoc, Don Hernandez-Permeasolo, has followed the river for three days, always in a northerly direction; warlike Igorots interfere with exploration, so that the farther course of the river is entirely unknown. In my mind there is no question that it flows into one of the western tributaries of the Rio Grande de Cagayan. Peñarubia also indicates this, although the course east of the cordillera is incorrectly shown.

The extremely amiable governor of Bontoc made it possible for me to make an excursion to the most northerly rancherias accessible, Meynit and Sadanga; he even accompanied us personally with military escort. A short distance from Bontoc we again encountered coralline limestone and breccias of coralline limestone and trachyte, which persist to Guinaan. From here, in the direction toward Meynit from Guinaan, there are beautiful green trachytes, which are very splintery, and show here and there isolated, decomposed crystals of feldspar. Bubbling forth from a flat area covered with mud and precipitated salts at Meynit are numerous boiling hot springs, flowing from the fissured ground and escaping as sizzling hot vapors. The vapors spread a faint odor of hydrogen sulphide; the water tastes brackish. The Igorots obtain salt from the hot vapors in a very peculiar manner. They build low straw huts over the fissured locality and cover the floor of the same with stones. Very soon there is formed over these stones thick white crusts of salt, the greater part of which consists of sodium chloride, which the Igorots sell.

The rancherias Meynit and Guinaan lie on a creek which flows into Bontoc River. In order to go from Meynit to Sacasaca, the cuartel of Sadanga, it is necessary to cross over a large mountain densely overgrown with pine trees. A raging thunderstorm and approaching darkness prevented all observations from this mountain.

The rancheria Sadanga is situated on a tributary of Bontoc River, and the cuartel is built upon a cliff some 500 feet high, made up of a decomposed rock rich in feldspar. A very clear, voluminous spring, having a temperature of 34° R. [42°.5 C.], gushes forth from a fissure in this rock. The taste is extraordinarily brackish, and the water precipitates much iron on the rim of the pool; a weak odor of hydrogen sulphide gas is noticeable. The Igorots believe that this spring possesses great healing power and utilize it in the treatment of various diseases.

On our return from Bontoc toward Cayan we followed the road as far as Sagada and then turned westward to the cuartel of Besao and southward toward Cayan. From Sagada to Cayan are doleritic rocks, with green slaglike augite, red olivine rich in iron, and decomposed feldspars, contained in a brown groundmass. The naked, yellow hills, up and down which one toils before reaching Cayan, consist of an entirely decomposed eruptive rock.

The advanced season of the year compelled me to break off my journey in the mountains here, if I were to visit the south of Luzon, and to return to Vigan via Angaqui, there to await the ship that was to take me to Manila.

Cervantes, situated on the left bank of Abra River, is reached by going

downhill over a good road from Cayan. The western face of the plateau of Cayan, toward the river, consists of a beautiful hornblende-andesite, which shows on a grand scale spherical segregations built up in concentric layers or shells. The outer shells are mostly very much decomposed; however, inside one encounters sound cores.

From Cervantes the road follows the left bank of the river; it was formerly called Camarin [camino?] del Rio. The valley is very broad here; to the east are the towering mountains of the cordillera; to the west, extending from north to south, is the costal range, whose profile is very jagged. The creeks that flow from its slopes into the Abra carry much coralline limestone, gravel, and decomposed amygdaloidal rocks. On both sides of the river up to 200 feet above its floor there are thick-bedded gravels, through which the road to Angaqui passes. Angaqui is a Christian village, situated on a knoll of coralline limestone on the left bank of the Abra. From Angaqui we crossed the coastal cordillera through Tovalina Pass at an elevation of about 3,500 feet. One of the most striking peaks of the range at Angaqui is Mount Tila, which because of its needlelike form reminded me very much of the Peter Bott in Mauritius.

Up to the pass the cordillera consists of a beautiful, partly crystalline, coralline limestone. The innumerable coral fragments are in a very poor state of preservation.

Very soon, however, after having reached the greatest height, which gives a splendid view of the ocean, on the steep western slope, there appear very thinly stratified, reddish, tufflike marls dipping south-southwest. They contain layers with carbonized plant remains. At Tianagan, the middle point of one of the auxiliary departments of the military district of Lepanto, these tuff-marls are very much folded and faulted. At Cayan I heard that coal had been found at Angaqui, but no one at this place knew anything about the occurrence. It is possible that it lies in a formation similar to the tuff-marl.

Throughout the country between Tianagan and Lilidda these tuff-marls occur alternating with thick strata of coralline limestone; one reaches the plain at Nueva Cobeta and proceeds to Santa on the seacoast. The coast at this point, several meters above high tide, consists of raised coral reefs which are still in contact with the growing coral. The massive rocks which occur in place in the vicinity are composed of quartz, orthoclase, and chlorite.

The city of Vigan, the second largest settlement on Luzon, is situated on a sandy, gravelly plain formed by the delta of Abra River. Abra River, as a whole, follows a north to south direction; east of Bangued, the capital of the military district of Abra, however, it turns suddenly to west-southwest, breaks though the coastal range in a narrow chasm at a point called the Bocada, about an hour's journey east of Vigan, and then divides itself into several branches, which rush toward the ocean through shifting channels. The Bocada, to which I made a little excursion, is cut into a complex of clearly stratified rocks, which as a whole show a steep westward inclination. This bedded series is composed of two kinds of rocks, frequently alternating with each other. One is a much crumpled chlorite schist closely traversed with calcite veins; the other rock is coarsely crystalline and is somewhat similar to a protogine gneiss like the rock we have already noted at Santa. For about one-half mile the river courses through this region of crystalline schist in a very narrow bed. At San Quentin the valley broadens, and one enters the district of Abra.

In order to reach Manila from Vigan, I boarded a steamer which went around the northwest point of Luzon to Lallo, on Cagayan River, took on tobacco there, and then without stop steamed to Manila. An opportunity was, therefore, given me to see, even though but hurriedly, the mouth of the Rio Grande de Cagayan. It is uncommonly broad and flat, and numerous sand banks which change their position each year after the rainy season make navigation difficult. It is possible to go as far as Tuguegarao, the capital of Cagayan Province, by using very light-draught steamers. It is to be hoped that the Spanish administration, which recently has been disposed to pay greater attention to this fine colony, will open the river, which is an important and beneficial artery of transportation for the tobacco district, by regulating and controlling its channel. At Lallo I found the banks of the river to be constituted almost entirely of heaps of *Anodonta* and *Unio* shells.

If we now review the observations made during my journey through northern Luzon, we shall distinguish five important groups of rocks: (1) The coral reefs and breccias of coralline limestone with recent volcanic rocks; (2) the tuffs and tuff-sandstones associated at places with coralline limestone beds and marls with plant remains; (3) recent eruptive rocks (quartz-trachyte, sanidine-hornblende-trachyte, hornblende-andesite, and dolerite); (4) the Agno beds, a mighty system of coarse sandstones and conglomerates, which have been derived from the underlying diabase and aphanitic rocks; and (5) diorite, protogine gneiss, and chlorine schist.

There can be no doubt that the coralline limestones belong to the most recent rocks occurring in northern Luzon. They always form the uppermost member of all formations, and with the exception of Benguet, where they are covered with a thin layer of red earth, I failed to find these limestones beneath other rocks. As has been said, they contain a number of coral fragments which, unfortunately, are in a poor state of preservation; they contain, although only in limited numbers, remains of lamellibranchs, gastropods, echinoderms, etc. All of these fossils have, however, suffered very much on account of the crystallization of the limestone. My highly honored friend, Mr. Neodor Fuchs, curator at the Imperial Cabinet in Vienna, at my request conducted an examination of corals occurring in the coral reefs of northern Luzon, as well as of the similar coral obtained at an earlier date in southern Luzon, and has reported his results as follows:

"The corals in question occurring in the limestone of northern and southern Luzon are in a condition of preservation that reminds one of our nummulitic limestones, so that according to European occurrences the specimens might from their outward appearence be considered at least as old as the Eocene."

A more extensive examination of the same material undertaken by me in conjunction with my honored friend Doctor von Marenzeller, in charge of the collection of the Zoölogical Court Cabinet, led also to substantially the same results.

Even though it was impossible to give a reliable specific report on account of the poor state of preservation of the fossils, it nevertheless was possible for us to declare with certainty that, with the exception of one single piece, which we could not identify, all of the rest belonged to genera which occur to-day in great abundance in the Indian Ocean, and even the individual corals can be referred without any question to living types. The corals

examined do not show the least relationship to the Tertiary corals from Java described by Reuss.

Regarded from this point of view, the raised coral reefs of Luzon must be considered as very recent in origin.

The genera identified by us are the following: *Galaxaea* sp., *Favia* sp., *Maeandina* sp., *Porites* 2 sp., (?) *Astraeopora* sp.

The stratigraphic as well as the palæontologic results go to show that the raised coral reefs of Luzon belong to the most recent geologic formation. One of the most noteworthy features of these reefs to my mind and at the same time a feature of highest geologic significance is their perfect stratification; how this stratification came about remains unanswered. I have seen similar coral reefs on the western coast of Luzon which were lifted only a few feet above the level of the sea; these showed the same peculiar property, which von. Mojsisovics has designated *übergossene Schichtung* in describing the Alpine coral reefs.

May not the stratification of the coral atoll of Benguet be attributed to a periodic cessation of the growth of the reef, perhaps caused by volcanic activity in the vicinity? I can scarcely accept the view that the stratification took place later, induced by metamorphism.

I bring this point into prominence, because Gümbel (Sitzungsberichte der mathemat.-physik. Classe der k. k. Akademie der Wissenschaften zu München, 1873, 3, 71–76) finds reason to deny the coral-reef nature of the *Schlerndolomiten* in the fact that they are stratified. Gümbel mentions the rare occurrence of thin layers of marl in the Schlerndolomit. I noticed, as was mentioned on page 39, very similar occurrences in the reefs of Sagada. Gümbel finds another argument against the coral-reef nature of the Schlern in the very rare occurrence of coral remains. We have seen how the geologically recent reefs of Luzon have been partly transformed into crystalline limestone. Even though it is indeed a peculiar thing that *Gyroporellen* are preserved very excellently whereas hardly anything is to be recognized of the corals, this should not be sufficient evidence to doubt the reef nature of the Schlern. Von Mojsisovics, on the other hand, defends the reef nature of the Schlern as follows:

"There can be no serious objection to the reef origin of the Schlerndolomit so long as we have no more than our present knowledge of the genesis of the lamination and stratification of homogeneous rocks." (Faunengebiete und Faciesgebilde der Triasperiode in den Ost-Alpen, Jahrb. der k. k. geolog. Reichsanstalt, 1874, 96.)

Semper has pointed out the rapid transformation of reefs into crystalline limestone and the noteworthy preservation of the structure in older corals. His remarks on page 100 of the second sketch, "The reefs and life in the Ocean," are worthy of great attention.

The most important facts, therefore, lead us to consider the entire Philippine Archipelago as being in a state of continuous elevation. The raised coral reefs still in contact with the living ones, to be found at all points on the coasts, as well as the geologically recent reefs at an elevation of 4,000 feet in the military districts, are examples which speak enough for themselves. In the Archipelago of the Philippines there are yet to be found living atolls, the growth of which, according to the theories of Darwin and Dana, must have been contemporaneous with a sinking of the ocean bottom. This data led the untiring Forscher to a closer examination of this

question. From the observations of Carpenter on the coast of Florida he holds that the formation of coral reefs is possible even from great depths and explains the different ways of emergence, by the influence of currents and other factors.

The presence of coral reefs elevated to a considerable height is not peculiar alone to those regions in the Philippines visited by me. Semper also mentions similar occurrences in northern and eastern Luzon and in Mindanao. Junghun also speaks of elevated coral reefs on the southern coast of Java.

The greater part of the tuffs and tuff-sandstones are unquestionably older than the raised coral reefs. These tuffs, even though we admit excessive faulting and folding, of which I could find no clear evidence, however, are extraordinarily widespread. From Aringay to Benguet, which has an elevation of 4,000 feet above sea level, they occur without interruption and likewise from Nueva Cobeta almost to the western slope of Tovalina Pass (nearly 2,000 feet). The included coral strata point to extended periods of rest in the formation of this complex, whereas the remains of dicotyledonous plants in the marls indicate the nearness of land. The coal measures of Angaqui and Aringay, which I did not examine personally, may very possibly form part of the same formation. In the basal rocks of northern Luzon, finally, we must include the Agno beds: diabase, gabbro, syenite, diorite, aphanite, and the protogine gneiss, which perhaps is the oldest of all. That the Agno beds have derived their material principally from the underlying greenstone and are, therefore, younger than the greenstone has already been mentioned.

It is highly interesting that a very similar bedded complex has also been found by Minard on the Island of Mindanao; it appears that in Mindanao these rocks are the source of gold (Sur les gisements d'or des Philippines, Bull. de la Société géolog. de France, 2, 3d series, 403). The gold is obtained from the gravels which the Rio de Iponan carried down from the interior, as well as from steep alluvial terraces which lie at the bases of the mountains. The most important rocks which are met with in Iponan Valley, according to Minard, are conglomerate and various kinds of sandstones with calcareous cement, covered over at many places by coralline limestone. The strata are broken through at numerous places by diorite and serpentine, and their inclination is about 12°. The stratigraphic order of these rocks is as follows: Shale (thickness unknown); conglomerate derived from various classes of rocks (thickness, 100 meters); grit derived from various classes of rocks (30 meters); argillaceous coralline limestone (30 meters); laminated clay (15 meters); ancient alluvium not gold-bearing (10–12 meters); recent gold-bearing alluvium (6–8 meters). The conglomerates are composed of the following kinds of rocks: 1, Black, coarsely laminated amphibolite; 2, diorite, with large amphibole crystals and triclinic feldspars as essential minerals and pyrite, quartz, and epidote as accessory minerals; 3, some specimens intermediate in character between the amphibole-diorite and the amphibolite-diorite of medium-grain size; 4, granitoid diorite with much mica; 5, aphanite; 6, granular marblelike feldspar in which granite and amphibole occur in bands; 7, serpentine diallage (magnetic), variety of ophiolite; 8, precious serpentine with asbestos veins; 9, diorite porphyry; 10, augite porphyry; 11, quartzose epidote; 12, jasper in beautiful modifications.

The gold-bearing alluvium is found in greater or lesser degree upon all the sedimentary formations enumerated, but principally on the conglomerate.

Here, as in northern Luzon, the dioritic-syenitic rocks are the gold-containers. The alluvium contains large quantities of mica, and according to Minard three native metals: gold, platinum, and lead. Daubrée noted the presence of zircon in the washed sand, which again points to syenite as the probable origin.

So far as concerns the relative ages of the different recent eruptive rocks it is impossible to determine anything with certainty. The eruption of all of these rocks may have taken place during the period of formation of the tuffs; and there is no evidence that the eruption of volcanic masses did not continue even after the elevation of the reefs. The still active solfatara of Aknal and the hot springs of Bontoc are the last stages of this wonderful phenomenon, which, perhaps, reached its greatest activity in the vicinity of Mount Data.

We are, therefore, led to conceive of the west part of northern Luzon as having consisted at one time of a mountain range of crystalline schist, which was elevated by mighty diabase and syenite eruptions, the fragments of which later were stratified into great sandstone and breccia-complexes. A long period of time perhaps elapsed between the deposition of the Agno beds and the renewed manifestation of volcanic activity. With the later vulcanism there were deposited large masses of tuff on the west coast; there must have been a contemporaneous subsidence of the sea floor to permit the deposition of such a great thickness of detritus. During the intervals of quiescence, even though of short duration, the corals could carry on their reef building. Vegetable remains transported from the mainland formed the plant-bearing marls. Even before the end of this period of subsidence it appears that volcanic activity had ceased. On the extensive submarine platform of tuffs the coral polyps built their structure and formed the coral reefs along the mainland which we now recognized in the Sierra Tovalina and in the detached peaks on the left bank of the Agno. Farther out in the sea atolls were formed, one of which we still find preserved in an excellent state in the valley of Benguet [Trinidad Valley].

An accurate knowledge of all of these individual reefs would enable us to make a correct estimate of the form of the mainland in those times, which apparently consisted of narrow islands having a north-south direction. Finally there began the period of elevation, which still continues, and which, judging from the age of the reefs, must pertain to a geologically recent period. The effect of this process of elevation was to join together the different islands as a related whole, in which we can easily distinguish, through the form of the land and the consequent direction of flow of the rivers (Abra, Agno, and Pan), a row of folds with north-south axes attaining the imposing height of 4,000 feet. This is unquestionably a very remarkable change of level within so short a time.

The Abra eroded its bed in the former channel between the mainland and the present coast range, the Sierra Tovalina, and utilized the large transverse cleft at Vigan to reach the sea. The two parallel-flowing rivers, Pan and Agno, may have flowed into the ocean-covered plains of Pampanga and Pangasinan at Niyong and Sto. Niño in very recent geological time. Only after these plains had been lifted out of the ocean, an event that may have been one of the last in the geologic history of Luzon, did they swerve westward and follow the gentle slope of the plain.

This might be, in very general terms, the geologic history of the western part of northern Luzon.

At the end of this monograph I shall try, in a summary, to correlate the formations noted on Luzon with those of Java, the only island in the Indian Ocean whose geology is thoroughly known.

GEOGRAPHY

TOPOGRAPHY

This region is typically mountainous, and from the character of the relief we must consider it as being in the stage of "topographic youth," as a glance at Plate II, which is characteristic, will at once make evident. Whatever might be said in general elucidation of this type of topography has already been said and written many times about similar forms of relief in geologically young parts of the earth and would only mean needless repetition here. However, a few facts should be noted.

There are two distinct types of topography in the region covered by this paper, and these are directly to be attributed to the character of the geologic formations. In the country to the west of the Polis Range the formations are mainly volcanic, and we find there an irregular, rugged, accentuated relief. The elevations vary from 370 meters to 2,400 meters or more.

East of this range the formations are folded sediments, giving rise to a more regular topography, and in places the hills and mountains are nothing more than tilted blocks of sandstone. On the eastern slopes these present long, gentle inclines, but to the west they form steep escarpments with here and there a saw-toothed skyline. As one goes farther to the east, approaching the valley of the Cagayan, the mountains become mere foothills.

Cagayan Valley, which I have not personally explored, though I have overlooked it from a number of points, is clearly synclinal.

In the eastern portion, between the high and low country just referred to, there is a stretch which has been called by Worcester "No Man's Land." The people inhabiting this tract will be referred to in a subsequent paragraph. The topography consists of medium-sized hills, from 370 to 430 meters in height, which are due to a cross folding of the originally flat-lying sediments. This cross folding produces hummocky hills and little pockety valleys or hollows.

CLIMATE

The climate of this region shows a complete gradation from subtropical in the bottoms of the large valleys, as, for instance, at Cervantes, to temperate in the more elevated portions. The lowest temperature that I experienced was at 5.30 on the morning

of March 11, 1914, on the summit of Mount Amuyao, 2,700 meters' elevation, when the thermometer registered 7°.8 C. At Bontoc, 945 meters' elevation, the temperature reaches this point in January.

As to the rainfall I can only say that at certain seasons (June to October in Bontoc and Kalinga) it is at times excessive, but the season differs in the several subprovinces. Again we find the Polis Range the great dividing line. On the eastern and southern side of this prominent topographic feature, in Ifugao, for instance, the seasons correspond more nearly to those which are found to obtain in the Cagayan Valley.

HYDROGRAPHY

The prominent features of the hydrography are the two principal streams, the Abra, rising on the slopes of Mount Data, flowing almost due north approximately to the town of Dolores, where it turns west by south and cuts through the coast range just south of Vigan, and the Chico which flows northeast and finally reaches the sea by way of the Cagayan. Neither of these streams is navigable in the area under discussion in this report. The main drainage in this area, then, is along well-defined, and doubtless structural, north and south lines with, of course, the usual attendant tributaries, which are influenced by purely local and minor topographic features.

VEGETATION

The region as a whole cannot be said to be a forest region. There are areas, such as those on the slopes of the Polis Range, which are fairly well-forested, chiefly with pine (*Pinus insularis* Endl.). There are other parts of the territory clad only with scattered timber, little of which is suited for anything but fuel, as around Bontoc and Lubuagan, while in Ifugao, particularly around Banaue, there is scarcely a stick of standing timber.

There is, of course, to be noted the usual vertical differentiation in the plant distribution quite constant throughout the Malayan province—that is, tropical flora at the lower elevations; from 760 to 1,830 meters, usually pine (not always, however); above this, the so-called "mossy forest;" and finally on the highest points only grass. The reader is referred to Merrill's [3] article on the flora of Mount Pulog, the highest peak in Luzon, situated just to the south of the country explored by me. What Merrill found on that mountain, I think, is typical of northern Luzon.

[3] *This Journal, Sec. C* (1910), 5, 287–370; 371–403.

The extreme low-country vegetation we no longer find anywhere in this region. This is important to bear in mind in connection with the fossil flora recently found at a high altitude and to which reference will be made on a subsequent page.

PEOPLE

The indigenous peoples of this northern country are essentially primitive and in most instances have been little influenced by outsiders. While a considerable number of tribes and corresponding dialects have been noted, they are ethnologically fairly homogeneous. It will suffice here to refer the reader to such authorities as Worcester [4] and Jenks [5] for fuller treatment.

GENERAL GEOLOGY

GENERAL STATEMENT

A cross section from the west coast at Tagudin northeastward to the edge of Cagayan Valley gives as good a general idea of the formations and structure of the region as one could expect to get by any procedure short of a detailed survey of the whole country. Fig. 2 is a graphic attempt to record my interpretation of the main facts.

Near the west coast we find gently folded shales and sandstone whose inclination increases as we go toward the Malaya Range, being much contorted as we get well into the cañon. The Malaya Range is essentially a mass of porphyry or, to be more exact, andesite. Some phases of it are aphanitic and are distinctly bluish green, indicating perhaps disseminated copper.

The town of Cervantes is situated on a small tongue of high ground between the Abra and one of its branches. The underlying rocks are practically the same as those found in the highland on both sides of the town. As we go toward Bontoc we find the same andesitic mass with, however, several large outcroppings of quartz.

When we reach Baguan and Sagada we find tuffs and reef limestones overlying this igneous mass. These tuffs dip 20°+ to the southeast, and although they are topographically higher than the limestones, in places the limestones lie stratigraphically above the tuffs. Subsidence of limestone would explain this.

From Sagada to Bontoc extrusive rocks, almost entirely an-

[4] The non-Christian tribes of Northern Luzon, *This Journal* (1906), 1, 791–875.

[5] The Bontoc Igorot, *Pub. P. I. Ethnol. Sur.* (1905), 1.

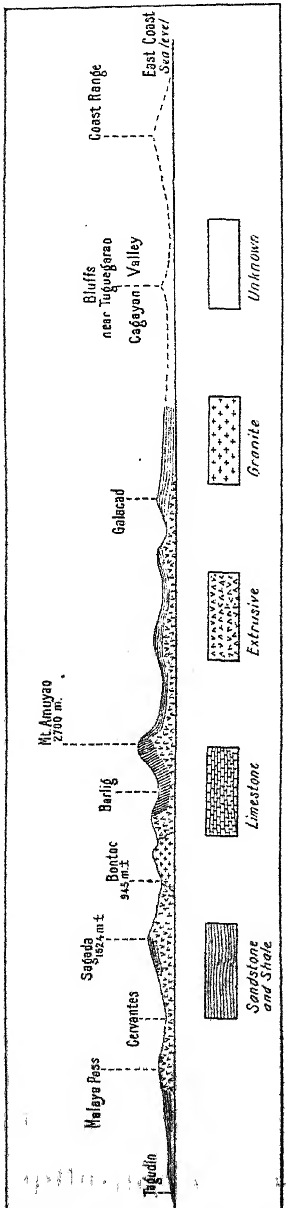


FIG. 2. Generalized geologic section across northern Luzon, from Tagudin to the eastern coast.

desites and dacites, are encountered but east of Bontoc the formation becomes very shortly diorite and granite. This belt of granitic rocks is only from 8 to 10 kilometers wide. There is more andesite, or rather a very fine-grained, almost aphanitic phase of diorite, succeeding the granite on the east as far as the town of Barlig, where steeply dipping sandy shales are encountered. These incline to the southeast.

Sandstone makes up the main mass of Mount Amuyao, and from there east to Cagayan Valley sediments occur. In places, as at Natonin, there are small areas of extrusive rocks overlying the Tertiary sediments. No limestone was seen east of Barlig, but farther north on the crest of the range east of Tinglayan I could detect limestone cliffs with the aid of a binocular. They are nearly 2,200 meters in elevation.

The apparent structure of the sediments in the eastern part of the section is indicated in the diagram.

THE PLUTONIC ROCKS

The plutonic rocks consist of granite and diorite.

The granite.—This formation was found at two points, a short distance east of Bontoc and in the Saltan Valley. It appears to be a long intrusive mass, whose axis runs from northwest to southeast. It is a typical quartz-feldspar-biotite granite and has a grayish to glaring white appearance in the

field. The feldspars are milky white. No microscopic examination of the feldspar has been made. The joining in this formation is particularly marked.

The diorite.—The diorite is a quartz-plagioclase-hornblende variety with some orthoclase and lies on both sides of the granite. Bordering the granite, and apparently in the diorite, are several large quartz bodies, which will be referred to again. These plutonic rocks are undoubtedly very much more extensive than they appear to be, but are concealed by the overlying extrusives.

The diorite I consider to be the basal formation, although it may subsequently be found to be intrusive as well. I regard the granite as an intrusion of rather recent date, equivalent to the late intrusion in the Paracale district farther south.

THE EXTRUSIVES

Von Drasche has already described the typical extrusives found in this region, and I have little to add to his list. However, he does not make any mention, I believe, of the occurrence of dacite, a glaring white rock with small phenocrysts of clear quartz in a dense, creamy white aphanitic groundmass. I found this well developed near the junction of the main Cervantes trail and the Sagada trail at kilometer 6, south of Bontoc. Its relation to the rest of the extrusive mass, which is andesitic, is difficult to make out even in the fresh cliffs along the trail. It may be an intrusive. It is not essentially different from the Corregidor rock.

There were undoubtedly several vents from which these extrusives issued, and one of these seems to be clearly indicated in a sort of broken-down craterlike topographic feature west and north of the town of Bontoc. The presence of tuff beds near the town dipping away from this center seems to bear out this supposition. Fig. 3 is a sketch of Bontoc and vicinity, showing the relationships obtaining there.

The list of extrusives, compiled both from von Drasche's and my own observations, includes: basalt, pyroxene-andesite, hornblende-andesite, andesitic agglomerate, dacite, and tuff.

A description [6] of the extrusives in the Benguet region applies essentially to the extrusive rocks farther north.

THE SEDIMENTARIES

The sedimentary rocks in this region include the following: Limestone, marl, tuff, tuffaceous sandstone, sandstone, shale, conglomerate, calcareous and siliceous sinter, and travertine.

[6] Smith, W. D., *This Journal, Sec. A* (1907), 2, 235.

Limestone.—Limestone in the high mountain region of Luzon is widespread though not necessarily extensive. It is manifested by remnants here and there, generally on the high mountain tops, and by "float" in the streams. One is led to believe that it formerly extended over practically the entire country.

The most extensive development of it is probably at Sagada, where we find it projecting from the soil and talus in great masses as shown in the photograph (Plate IV). The bedding planes, which can be distinctly made out even in the picture, dip about 20° southeast. On the weathered surfaces the stone

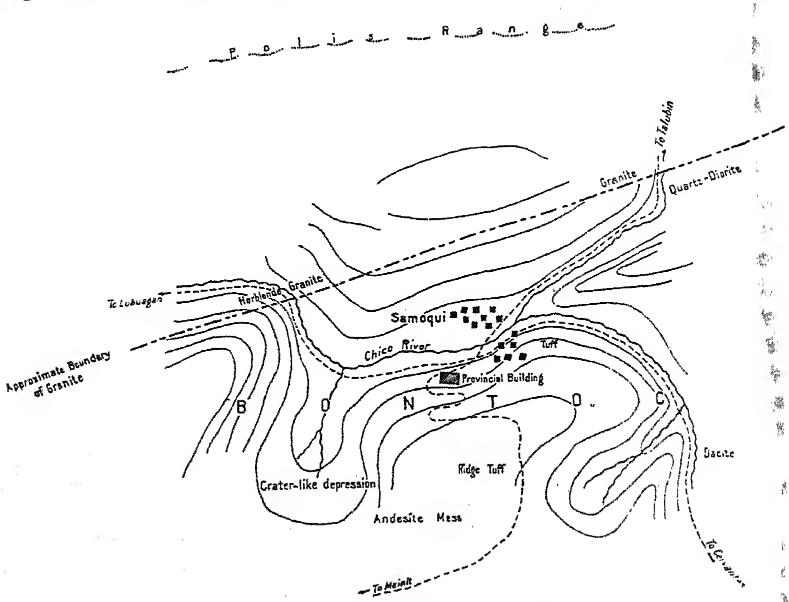


FIG. 3. Sketch of the vicinity of Bontoc.

is bluish gray, but on fresh fracture it is cream white to reddish. Plate IV, fig. 2, shows the characteristic spirelike forms produced by the dissolving action of the heavy rainfall of this region.

A thin section of the rock shows innumerable fragments of the well-known Mio-Pliocene marine alga, *Lithothamnium ramosissimum* Reuss. This formation, therefore, is equivalent to the upper limestone in Cebu and many other parts of the Archipelago.

In this limestone at Sagada are numerous sinks and some caves. In the entrance chambers of the caves the Igorots place their dead. One cave has a chamber as large as the auditorium of a

small theater and is said to have passages several kilometers in length. I made no extensive exploration of these, as I felt that this was purely a side issue, having no fundamental bearing on the more general field studies then in hand. Cave exploration in this region would probably not yield any paleontological results as the amount of water carried through these passages at certain seasons would undoubtedly remove any such remains.

In another way their exploration is of practical value. For instance, near Baguio just the same sort of cavernous limestone, in places concealed by the tuff and talus, has been responsible for some very serious slides along the Benguet road. And, also, at Sagada I think the limestone must be held responsible for some rather extensive landslides.

In traversing the hills about Sagada (just south of the mission), I found a conglomerate of apparently purely local development above the limestone. It consists of a sandy and reddish matrix with limestone pebbles in it. This conglomerate is not to be correlated with the "Agno beds," which are far below both topographically and stratigraphically.

Marl.—Von Drasche has already called attention to the marly layers intercalated in the upper limestone near Sagada. These can be seen in several places in the road south of the Mission, but they are only thin layers and are not of any economic importance. The marl is buff-colored.

Tuff.—As would be expected in a region of formerly great vulcanism, tuff beds are a dominant feature of the sedimentaries. At Sagada, where Father Staunton, of the Sagada Mission, has opened a quarry to secure material for his new church, is perhaps the best section of the tuff beds to be seen anywhere in the province. The face of the quarry is about 15 meters high and reveals the following beds:

1. Soil and loose material.
2. Tuff in heavy beds, 1.5 to 3 meters.
3. Yellow-stained shale, 0.5 meter.
4. Tuff in solid bed with varying texture, 18 meters.
5. Bluish black shaly-looking rock which is very fine-grained, 1 meter.

In this section the strata appear to be nearly horizontal, as the face is approximately along the strike. The dip is about 20° to the southeast. In the shaly portions are great numbers of leaf impressions, some fine specimens of which I secured through the assistance of Mr. McBrust, the engineer of the Sagada Mission. These leaf impressions are so perfect and so much like some of the living lowland plants that I submitted them to

Mr. E. D. Merrill, botanist of the Bureau of Science, for identification. His illuminating notes are inserted here:

The fossil remains, mostly remarkably clear leaf impressions, all, or nearly all, represent species still living in the Philippines at low and medium altitudes, and an examination of the material shows that the forest in the Bontoc locality was a typical mixed dipterocarp forest such as is found to-day in all parts of the Philippines, where primeval vegetation persists, from sea level to an altitude of about 800 meters. None of the species is found to-day within the limits of Bontoc subprovince, and very few of them are to be found in any part of Mountain Province. None of them is found above an altitude of approximately 800 meters, while the present altitude of the fossil-bearing strata is 1,500 meters.

DIPTEROCARPACEAE

SHOREA POLYSPERMA Merr. (Tanguile).

Impressions match leaves from living trees beautifully. Throughout the greater part of the Philippines at low and medium altitudes, ascending to about 700 meters. Common. Endemic.

SHOREA GUISO Bl. (Guiso).

Throughout the greater part of the Philippines at low altitudes, abundant. Ascends to at least 500 meters. Endemic.

SHOREA sp. (may be *S. eximia* Miq.).

Like the preceding, but less common. Malaya.

ANISOPTERA THURIFERA Bl. ?

Widely distributed at low altitudes. Endemic. The identification must be considered doubtful, but it is certainly a dipterocarp.

LAURACEAE

BEILSCHMIEDIA CAIROCAN Vid. (Cairocan).

Widely distributed in the northern and central Philippines at low and medium altitudes. Ascends to perhaps 500 meters. Endemic.

PHOEBE STERCULIOIDES Mess.

Like the preceding, but in all or most parts of the Philippines at low altitudes. Ascends to 500 meters.

GUTTIFERAE

CALOPHYLLUM BLANCOI Pl. & Tr. (Palo maria del monte).

Widely distributed in the northern and central Philippines at low and medium altitudes. Ascends to 600 meters. Endemic, unless the same is a Malayan species.

TILIACEAE

DIPLODISCUS PANICULATUS Turcz. (Bolobo).

Throughout the Philippines at low altitudes, ascending to 500 meters. Common and abundant. A monotypic, endemic genus.

MENISPERMACEAE

ANAMIRTA COCCULUS W. & A. (Suma).

Widely distributed in the Philippines at low and medium altitudes. India to Malaya.

CYPERACEAE

MAPANIA HUMILIS F.-Vill.

The identification is not certain. The species is found throughout the Philippines in mixed forests from sea level to 600 meters and is abundant locally. The impression may be that of a leaflet of *Calamus* sp. (Palmae).

INDETERMINABLE

Cast of a fruit that conceivably may be that of a more or less distorted *Pterospermum* (Sterculiaceae).

Faint impression of a crushed stem or a monocotyledonous leaf. Quite indeterminable.

Imperfect remains of several other kinds of leaves, the material quite indeterminable.

These tuff beds are in all likelihood equivalent to the great series of tuff beds in Java in which *Pithecanthropus erectus* Du Bois was found, and which were once thought to be Pliocene, but have recently been shown by Schuster[7] to be Pleistocene. Schuster bases his conclusions upon the plant remains inclosed in the strata. Special attention is invited to Plate XXVII of Schuster's work, where a graphic section of the tuff strata exposed at Trinil is given.

The conclusion to be drawn from the presence of these fossil leaves is clearly that there has been very recent and very pronounced elevation in this part of Luzon. It does not argue a change in climate in the Philippine region other than that attendant upon a change of elevation. All the evidence we now have points to the fact that there probably has been little or no regional change in climate throughout the Tertiary and Post-Tertiary in this part of the world. The fact that the nipa palm, now growing in the Philippines, is found fossilized in the London clay (Miocene) indicates that essentially Tertiary conditions still prevail in this part of the world.

In 1911 there was a landslide of considerable extent in this region, due probably in part to the tuff and in part to the limestone as indicated in the diagram in fig. 4. The subsidence amounted to as much as 15 meters in places and carried the entire village of Ambasing with it. The line of the fault can still be seen on the hillside. The area affected is about 2.5 square kilometers.

[7] Schuster, Julius, Monographie der Fossilen der Pithecanthropus Schichten, *Abh. d. k. bayr. Akad. Wiss.* (1911), 25, Abh. 6.

Tuffaceous sandstone.—Throughout this region, but particularly near the volcanic area, are beds which can with difficulty be differentiated from tuff on the one hand and true sandstones on the other. This material is found in its most puzzling aspect at Lubuagan, the capital of Kalinga. The truth of the matter is that the constituents of both the tuff and the sandstone came from the disintegration of volcanic rocks. Whether they were derived from material blown out by explosion or by subsequent erosion can only be told by examination of the shape and condition of the component grains. The point is that the constituents in both cases may be much the same. As one goes eastward it becomes easier to make these distinctions.

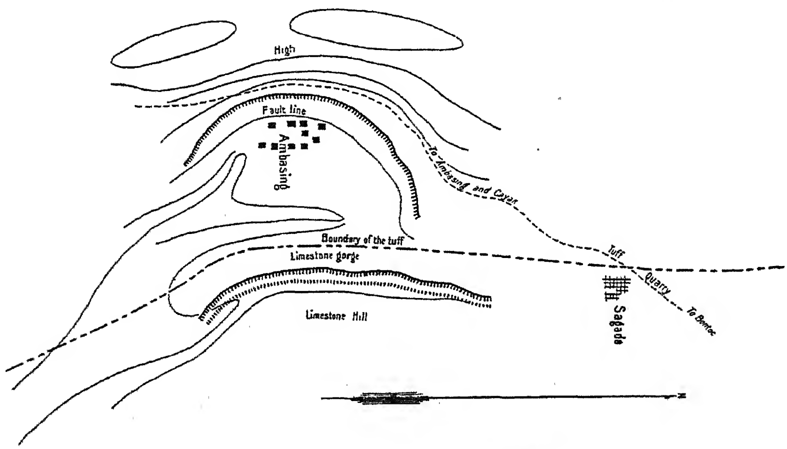


FIG. 4. Sketch showing slide near Sagada.

Sandstone.—A typical exposure of what might be termed the Kalinga sandstone is found on the banks of Chico River near the Nipon resthouse. At this place the sandstone and alternating shale beds are exposed for almost a kilometer on the west bank of the river. The dip of these beds is 65° and a trifle to the north of west. The sandstone is a coarse, grayish to buff material, which shows plainly its derivation from andesitic rocks. Along the bedding planes ripple and wave marks are very plain and abundant. There also was seen an impression apparently made by a long-stemmed reedlike plant. Unfortunately this specimen is too imperfect for identification. It is possibly the remains of a gigantic sea weed, or a reed which grew in brackish water or in the swamps near the sea. No animal remains were found in this exposure, but at a road camp along the trail between

Lubuagan and Sician, in the sandy shale portions of what must be the same series, I found the following forms:

Turbo borneënsis Bttgr. (?).
Pecten senatorius K. Mart.
Pecten leopardus K. Mart.
Cardium sp.
Conus sp.
Cycloseris decipiens K. Mart.
Cassidaria sp.
Tapes sp.
Dosinia sp.
Turbinella tjidamarensis K. Mart.
Fragments of Alcyonaria.

The presence of these fossils stamp this formation as Mio-Pliocene.

Shales.—The shales which are found intercalated in the sandstones of this region grade imperceptibly into them. Mineralogically they are the same and differ merely in grain size. Plate V, fig. 1, gives an excellent idea of their field occurrence. The thickness of these beds would in the aggregate amount to from 300 to 600 meters. The repeated alternation of sandy and shaly layers in practically all of the sections, but particularly in this one, indicates that these beds were laid down in shallow water.

The cliff shown in the photograph is one of the most dangerous on the trail between Bontoc and Lubuagan, due to the crumbling nature of the beds, together with the inclination, which is approximately 45°. No fossils have been found here.

The conglomerate.—I have alluded already to a local conglomerate associated with the limestone at Sagada, but the one I shall refer to now is the basal conglomerate equivalent to the "Agno beds" of von Drasche. It does not appear to be developed to the extent of the beds in the type locality on Agno River or along Bued River. This formation is mineralogically the same as the sandstone and the shale, the difference again being one of grain size. Naturally we find andesitic and dioritic material predominating, as these rocks predominated in the ancient headlands of the Tertiary seas. It is very easy to confuse some of the conglomerates with the volcanic agglomerates. Also the sandstones, in places, through concentric weathering, simulate the conglomerates. I have no idea at present of the thickness or extent of these conglomerates.

Sinter.—In this region hot springs are occasionally found where great quantities of siliceous and calcareous sinter are to be seen. At Salinas, in Asin Valley, one finds the best and most beautiful deposits (Plate V, fig. 2). At Mainit, near Bontoc, there are terraces, but the Balotoc hot spring deposits practically no sinter.

Travertine.—We cannot omit from a complete list of sedimentaries the ubiquitous deposits of travertine here and there in the

streams, attesting the presence of a limestone remnant somewhere farther upstream. As pointed out in discussing other parts of the Archipelago this deposit is found most abundantly on shale, and wherever it occurs it completely obliterates the rocks beneath.

STRUCTURE

The generalized cross section will give a clearer idea of the structure in the province than any amount of description.

Considering northern Luzon broadly, we note on the extreme east an anticline (presumably—I have no specific information concerning the structure of the eastern cordillera) with the Cagayan syncline, or trough, immediately to the west. From this trough the sedimentaries rise gradually, with minor folds, in a long monocline until they abut on the igneous complex of the Cordillera Central. To the west of the cordillera is the long tectonic trough occupied by Abra River. It is not yet proved whether this is a rift valley or not, but certainly it has a strong resemblance to one. As much of the country has been covered with volcanic ejecta, it is difficult without more field work to discuss the structure in many parts of the region.

It is not unlikely that there was a broad, gentle arch of younger sediments, chiefly limestone, over the Cordillera Central, judging from remnants of this formation on the crests of some of the highest ranges, but even here the evidence is not sufficient. Eveland [8] has already suggested this.

In conclusion, we may say that the grain (to use a word employed by Professor Gregory, of Glasgow) of northern Luzon is north and south, as we would expect from a glance at the alignment of its topographic features alone. Many irregularities in strike and dip with faults complicate the study of the region.

GEOLOGIC HISTORY

It is a question whether any one has done enough geologic work in this part of Luzon to give other than suggestions of the geologic history. Von Drasche does not say enough about the sediments in this region, undoubtedly because he did not get far enough eastward to encounter them. Not only was there a long period of subsidence, but this was interrupted by minor oscillations of level as indicated by the rapid change in the character of the sediments. He says nothing about the great

[8] *This Journal, Sec. A* (1907), 2, 207.

earth movements as indicated by the present folded condition of these sediments.

One would get the impression from von Drasche that considerable quantities of plant remains are to be found in the marl beds. I found none in the marl, but all were in the tuff beds. I saw no schist in that part of the area I explored.

ECONOMIC GEOLOGY

The economic portion of this report will of necessity be brief. The semiwild state of most of the territory and the comparatively untutored condition of the people, of course, precludes any but the most rudimentary utilization of the mineral resources. In the following discussion I shall consider not only the useful minerals known to exist but some possibilities as well.

NONMETALS

Clay products.—There are undoubtedly many localities within this territory where both residual and transported clays can be obtained. Pottery making is here, as throughout the Philippines, a household industry. The chief locality for its manufacture is at the town of Samoqui, just across the river from Bontoc. The clay is very poor and sandy and burns red. There is some attempt at decoration, and there is a slight glaze given to the pots by the use of resin, if I am correctly informed. This industry has been described by Jenks.[9]

On the Bontoc side a fair grade of red brick is made by Igorots under the superintendence of Americans. All of the public buildings of the capital of the province have been constructed of this brick. The industry was started by John Early, formerly a school-teacher stationed at Bontoc. The effect of these brick structures is a very pleasing one. Apparently there have been no earthquakes of sufficient importance to cause any damage, and with the exception of this danger this type of construction seems to be excellently adapted to the country.

Sand-lime brick could easily be made in many localities in this section. The principal cost would lie in the generation of steam, and the manufacture might not be economical on that score.

Coal.—Thin streaks of coal have been reported from various places in Mountain Province, but I have not seen any that promise to be of commercial value. I believe that the changes

[9] Op. cit.

in sedimentation were so rapid as to preclude the formation of workable thicknesses of coal. Farther east in the syncline occupied by Cagayan Valley, where quieter conditions prevailed and gradual subsidence took place, coal deposits could and did form.[10]

Lime.—As limestone is found at many points in the province, if not always in place, in stream bowlders in great numbers, an abundance of lime could be made. At present practically the only limestone burned is at the Sagada Mission, where Father Staunton has installed two iron kilns of foreign make. As already mentioned, there is an abundance of pure white (and some reddish) limestone belonging to the Pliocene epoch, which makes a very good lime. According to Mr. McBrust a very good hydraulic lime is secured by burning the red variety. The supply is practically all used locally.

Oil.—As yet no oil seeps have been reported from this part of Luzon, but it is not improbable that such may be found in the sedimentary area in the eastern part of this region where the structure is not unfavorable.

Salt.—The three best-known salt springs in this region are, beginning at the south:

1. Salinas, located in the Asin Valley. This has been described by Cox.[11]

2. Mainit, located about 12 kilometers northwest of Bontoc, which has been described by Jenks.[12]

3. Balotoc, located about 10 kilometers east from Lubuagan. The trail to Balotoc is about 20 kilometers long, and the traveling is pretty rough in places. This spring differs very materially from the other two in that in the first two there is a considerable deposit of calcareous and siliceous sinter with a small amount of salt, whereas in the latter there is no appreciable deposition of sinter, but the water as it issues from the spring seems to be saturated with salt. The process of concentrating the salt for use is, therefore, a very simple one, as the natives simply run the water through bamboo tubes into caldrons, where the water is evaporated by boiling. At Mainit and Salinas the operation requires as much as three months, while at Balotoc only a day or so is necessary. The headman at this place told us that he recovered seven packages, of about 5 kilograms each, per week in one caldron.

[10] Cf. Ferguson, H. G., *This Journal, Sec. A* (1908), 3, 535.
[11] *Min. Res. P. I. for 1911* (1912), 63.
[12] Op. cit.

The country rock at both Mainit and Balotoc is andesite. The water bubbles up at boiling temperature from very small fissures. At the former locality the spring is located in the bottom of a gully and gives rise to a small stream, but at Balotoc the water issues from the bank of Tabia River. In the rainy season the water in the river rises above the vents, and all operations have to cease.

Following are analyses of the two waters made after both had stood sealed for several weeks:

TABLE I.—*Analyses of waters from hot springs, northern Luzon.*[a]

[Figures give parts per million.]

Constituent.	Mainit.	Balotoc.
Silica (SiO_2)	195.0	317.5
Ferric oxide and alumina (R_2O_3)	88.0	85.0
Calcium oxide (CaO)	127.5	867.5
Magnesium oxide (MgO)	1.1	7.1
Sodium oxide (Na_2O)	457.0	8,688.0
Potassium oxide (K_2O)	23.1	1,579.6
Carbonic acid radical (CO_3)	208.2	----------
Sulphuric acid radical (SO_4)	295.4	236.1
Chlorine (Cl)	752.6	11,590.0
Total	2,147.9	23,370.8

[a] Samples collected by W. D. Smith. Analyses by Dar Juan, chemist, Bureau of Science, Manila. Sp. gr. at 33° C., 1.010.

From these we note particularly two things: namely, the great difference in the sodium chloride content of the two waters and the apparent discrepancy in the case of the silica. This is explained by the fact that the silica of the Mainit water is deposited at once and almost before it can be bottled.

It might be asked whether the existence of buried deposits in beds is indicated by these waters. I do not think so, but believe that the action of subterranean waters of some kind on the igneous rocks will account for the presence of these springs. There are, at least, no surface indications of sediments of any kind in the vicinity.

Sulphur.—About 2 kilometers southeast and perhaps 300 meters above and across the river from the Balotoc springs are eight large steam vents from which copious sulphur fumes issue, and deposited about these are several hundred tons of sulphur. It is said that the insurgents had planned a powder factory here during the late insurrection, but it is evident that they did nothing more than talk about it. This sulphur in its present location has no commercial value. There are likewise

some small vents near the river 30 meters or so upstream from the salt springs. The whole countryside shows evidence of dying vulcanism.

Road metal.—For the most part the only highways in this country are horse trails; consequently there is at present little demand for road metal, but we can assert with entire assurance that there will never be any dearth of suitable material when it is needed. There is no lack of "trap rock," which term the road engineer employs to designate several varieties of igneous rock. A very good stone for the traffic utilizing it is now used on the streets of Bontoc. It is a whitish rock, some phases of which resemble dacite, and affords a firm, hard, quickly drying surface. It is abundant just south of the town.

Building stone.—Stone for construction purposes is quarried in two localities. One of these is a gray, impure sandstone, derived from the débris of andesitic rocks, which occurs at Kiangan; the other is a tuffaceous sandstone at Sagada. The two are superficially much alike.

At Lubuagan the school authorities are planning to use a similar stone for building a schoolhouse. My opinion, which has been asked for by local authorities, is that this stone, while superficially much like the stone in the other localities mentioned, is really of very inferior quality. It is a grayish, tuffaceous sandstone, fairly fine-grained, in places coarse, and composed of andesitic detritus. The chief mineral fragments are lime-soda feldspars and hornblende with little or no quartz. A block of this stone, with a bearing surface of 11.8 centimeters by 12.8 centimeters, was subjected to a compression test with the result that it yielded at 348 kilograms per square centimeter without giving a cone. In fact it broke along parallel planes, indicating that the pressure had been applied parallel to the bedding planes (there was nothing to indicate beforehand how these lay). Although this figure is low, it is higher than that (329 kilograms per square centimeter) given for a superior sandstone when compressed along the bedding planes. It is reasonable to suppose that the Lubuagan tuff would withstand a greater load if it were applied at right angles to the bedding planes, and it follows that in construction the stone should be laid with the bedding plane horizontal.

The most unfavorable feature of the Lubuagan stone is its tendency to crack and sprawl on exposure.

I have no figures for the Sagada stone, but as it hardens on exposure it ought to serve very well in structures of moderate

size. This stone is not a "blue limestone," as it is locally called, but a tuff. It has a decided bluish cast, and considering the ease with which it can be dressed, makes a very suitable building stone.

WATER

Potable water.—The country west of the Polis Range abounds in springs of excellent water, which I have personally utilized, but eastward, in the sedimentary area, the water is not as good. However, whenever the state of the population demands it, good artesian water can be secured there, as the formations are apparently favorable.

Medicinal water.—The hot water at Mainit is said by the natives of that town to be used by them both for drinking and bathing. They assert, also, that they are practically free from diseases of any kind, particularly skin diseases. Certainly the inhabitants of Mainit are in striking contrast to those of Natonin, for instance, where practically the whole population is afflicted with loathsome skin diseases.

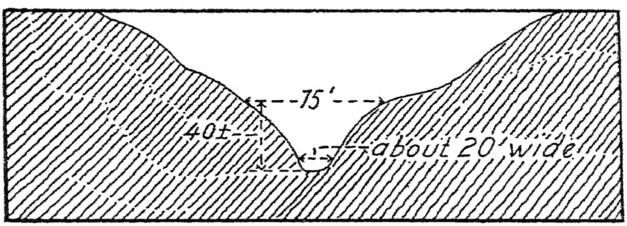


FIG. 5. Profile of box cañon at kilometer 6, south of Bontoc.

What curative effects are derived from the Balotoc water I do not know, but the people living near those springs are likewise free from skin troubles.

Power.—Power sites in this mountainous country and region of bounteous rainfall are, of course, innumerable. At present there is little demand for power. At Fidelisan, just north of Sagada, Father Staunton has constructed a flume from which the water drops 45 meters through a 4-inch pipe to a Pelton wheel, and with the power thus obtained runs a large saw and planing mill. Since storage reservoirs cannot as a rule withstand the tremendous rainfall, the best method of utilizing the streams is by means of diversion weirs and flumes.

However, an excellent site for a storage reservoir, which will be available at some future time for the growing city of Bontoc, is located at kilometer 6, south of Bontoc, at the "suspension

bridge." At this point a stream from the west joins the Chico through a fine box cañon in solid andesite. The cross section is about like that reproduced in the diagram (fig. 5).

Above the box cañon the valley widens out, affording a very considerable impounding area. This valley does not appear to be particularly populous, so there ought not to be much difficulty in persuading the people to move to other sites. The dam would be located within a few meters of the main road into Bontoc, and Igorots could efficiently perform all the labor, as they are already skilled in rock work.

METALS

Mountain Province, of course, has one, presumably, very valuable mineral asset in the well-known Mancayan copper deposits. As these have long since received attention from geologists [13] and engineers, there is no need of describing them here.

Northward there are indications of copper, but these are in the Cordillera Central and not eastward, where most of my work was carried on. I neither saw nor heard of any copper deposits in the Polis Range.

Gold.—Eastward from Bontoc, at a point about 4 kilometers distant, granite is encountered, and this continues for several kilometers. As already outlined, this formation extends northward at least as far as Balbalasan. On the western side of this, toward Talubin, I came across several large quartz lodes, outcrop samples of which were assayed, but gave only "traces" of gold. However, as these were only "grass root" samples, it is not conclusive that values are not to be found in the lodes farther from the surface. One of these lodes is about 30 meters wide, striking about north and south, and is nearly vertical. I merely mention these as possibilities for the prospector to look into. The Igorots have never, as far as I could learn, found any free gold in the Bontoc region. It is my opinion, on the other hand, that a granite intrusion like this one will ultimately be found to have caused the deposition of some minerals of value near it. I should not omit to mention that there is more or less iron-stained quartz in Fidelisan Valley near the Sagada Mission sawmill, which has attracted more or less attention from prospectors. Samples taken by me from the face of the ledge gave only a "trace." It is said that the gravel in the ancient banks of this stream about 60 meters above the gorge carries

[13] Eveland, A. J., *This Journal, Sec. A* (1907), 2, 207.

values. It is doubtful if the proposition would be sufficiently remunerative to warrant an expensive installation of machinery.

Iron.—The existence of iron deposits along the Balbalasan trail was reported to me in Lubuagan, but I found nothing but bog ore in the course of deposition at the two places to which I had had my attention called. On the east bank of Saltan River, about 1 kilometer north of Balbalasan, I found a small float bowlder of hematite, but saw no deposit in situ. This locality would hardly be worth prospecting for anything but gold on account of transportation difficulties.

SUMMARY

1. Mountain Province, as its name implies, is for the most part mountainous. The chief valley and place of settlement is the tectonic valley of the Abra. The province is inhabited by semi-civilized peoples who live in widely scattered communities, and the town is the chief political unit. Many different dialects are spoken.

2. The geologic formations west of the Polis Range are volcanic and plutonic; eastward they are sedimentary. The human response to physiographic and geologic conditions has been marked.

3. The sedimentary formations are, as far as known, Tertiary.

4. There are indications of mineral deposits which might be of economic value, but which are not exploited.

5. Agriculture on a small scale and the limited and not easily accessible forests are practically the only resources of the country, and these cannot of themselves develop it much beyond its present state. The mining industry, apparently, holds out the only hope for the province.

ILLUSTRATIONS

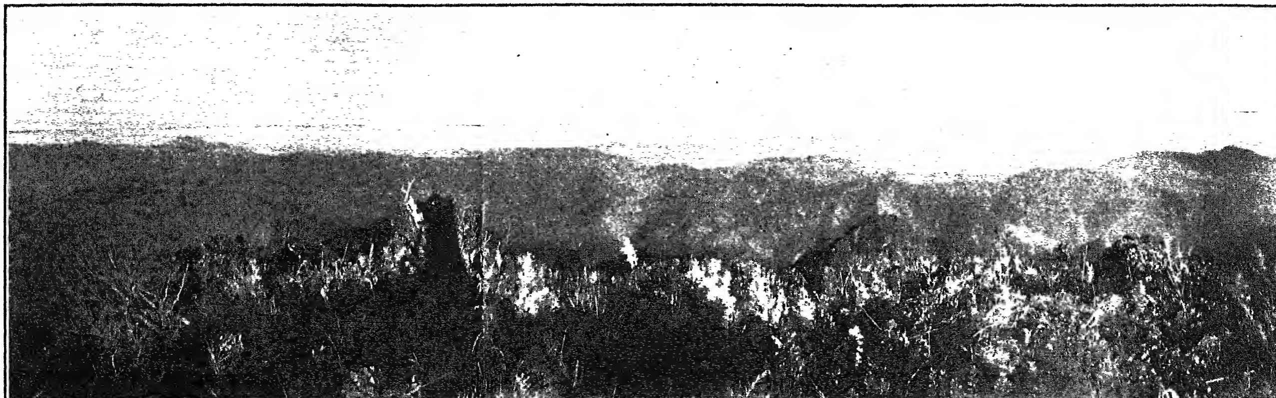


PLATE I. PANORAMA FROM MOUNT AMUYAO TO THE SOUTHWEST.

Fig. 1. Malaya Range across Abra Valley from near Cervantes.

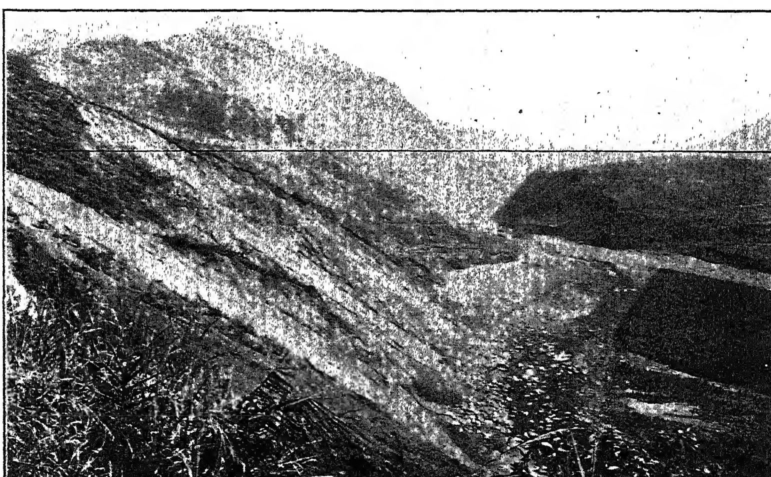


Fig. 2. Abra River between Tinglayan and Lubuagan.

PLATE II.

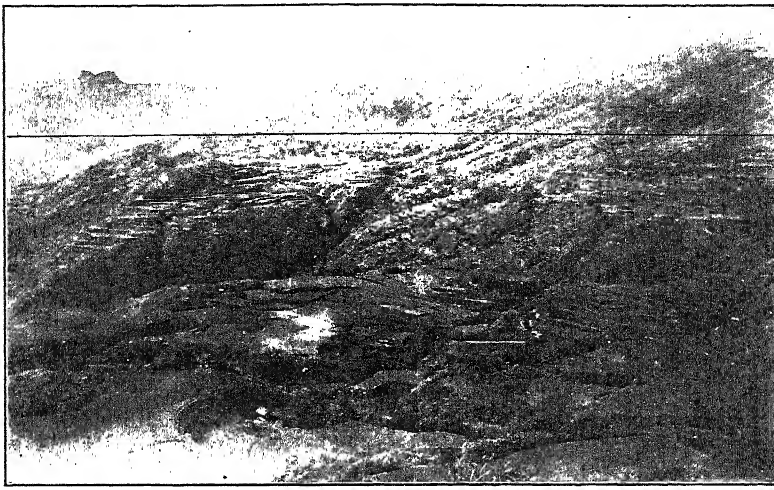


Fig. 1. Rice terraces at Lubuagan; three crops are obtained each year here.

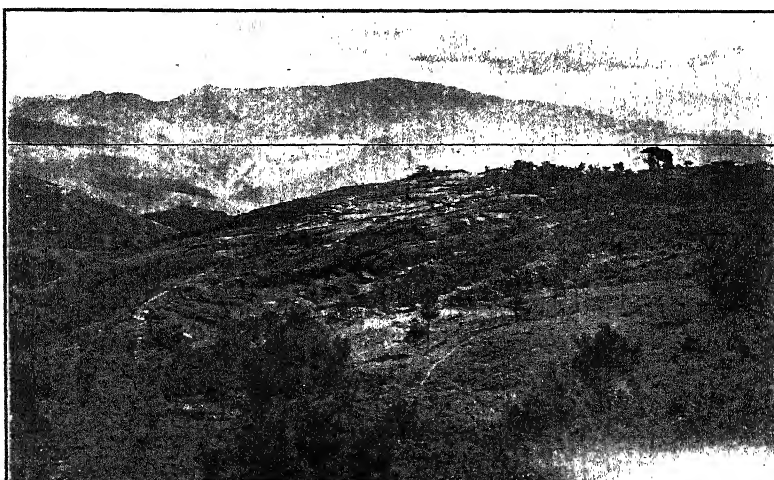


Fig. 2. Topography in the region of extrusive rocks; looking southeast from near Tadian. In the middle distance is an old volcanic plug.

PLATE III.

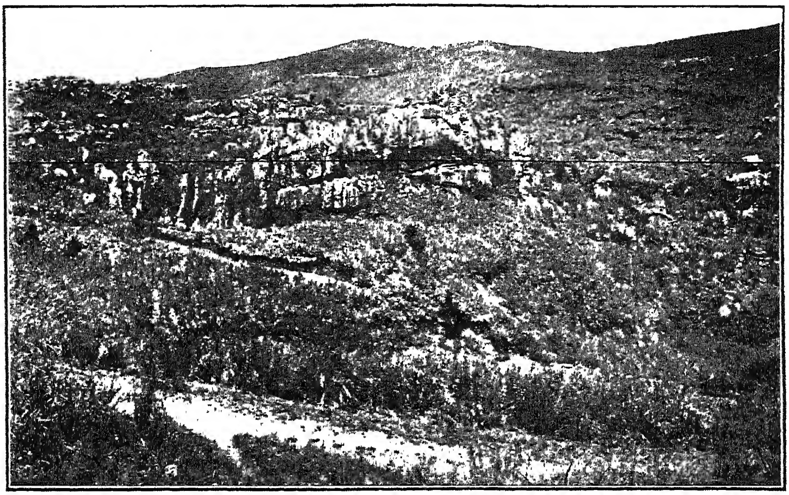


Fig. 1. Limestone at Sagada.

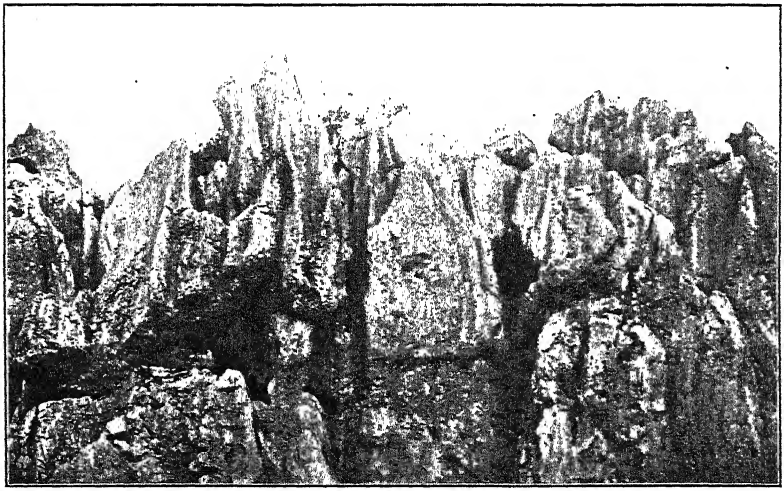


Fig. 2. Nearer view of Sagada limestone, showing weathered forms.

PLATE IV.

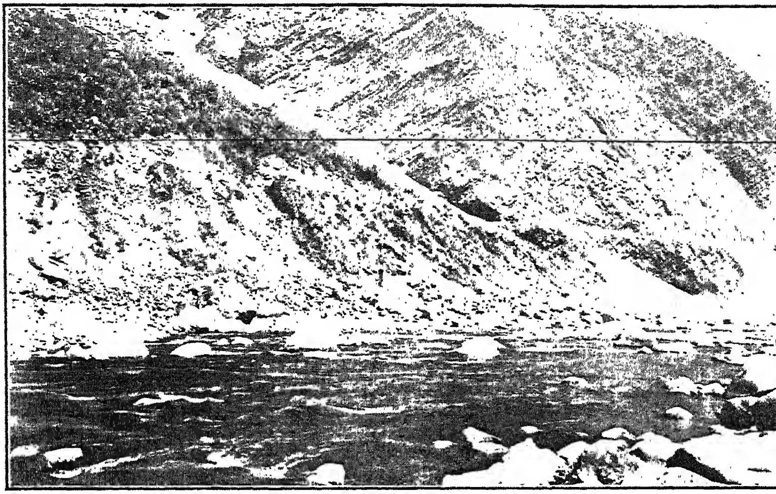


Fig. 1. Shale beds in trail to Lubuagan.

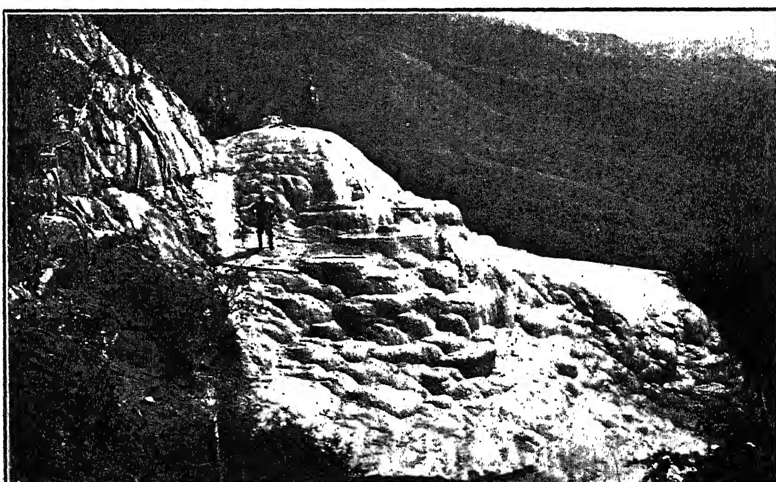


Fig. 2. Terraces at Salinas salt spring.

PLATE V.

NOTES ON THE GEOLOGY OF PANAY[1]

By WARREN D. SMITH

(*From the Division of Mines, Bureau of Science, Manila, P. I.*)

ONE PLATE AND 3 TEXT FIGURES

CONTENTS

INTRODUCTION

Between the years 1886 and 1890 Enrique Abella y Casariego[2] carried on geologic investigations in the Island of Panay assisted by d'Almonte. The report of his work embraces detailed descriptions of the general geologic features of the country, including orography, hydrography, with the altitude of all the principal points, followed by chapters dealing with the volcanic formations and their "tufas." There are also chapters dealing with the sedimentary formations, particularly the Tertiary series, and the work closes with a part devoted to the economic geology. It is very complete as far as it goes, but omits many important points, which is to be expected when the geology of an unknown country is treated for the first time.

Mr. Maurice Goodman, formerly of the Bureau of Science, touched at a few places on Panay in the latter part of 1905, about fifteen years after Abella. The purpose of his trip was to discover workable deposits of sulphur, gypsum, limestone, building stone, and placer gold. His stay in Panay was less than ten days. He found no deposits of either sulphur or gypsum, but the time was all too short properly to pass upon the mineral resources of any district. Mr. Goodman obtained several specimens of limestone from various points in the eastern part of Panay, the

[1] Received for publication November 27, 1914.

[2] Descripcion fisica, geol. y min. de la Isla de Panay. Chofré, Manila (1890).

analyses of which are given in his manuscript report. These show fairly pure limestone, usually with less than 1 per cent of magnesium oxide.

In the summer of 1912 Mr. Wallace E. Pratt, a geologist of the Bureau of Science, was detailed to make a rapid reconnaissance of the region about the town of Janiuay at the edge of the foothills on the eastern side of the cordillera in order to ascertain the possibilities of finding petroleum in the sedimentary formations. During his work on Suague River, which flows past the town of Janiuay, it occurred to him that there were artesian-water possibilities in that region, and he reported this to the Director of the Bureau of Science.

In the latter part of December, 1912, I was detailed to follow up the suggestions made by Mr. Pratt in regard to artesian-water possibilities, in an effort to aid the Director of Public Works in the important project of providing the city of Iloilo with an adequate supply of pure water. During the course of this work, which was confined rather closely to that section of the country immediately northwest of the city of Iloilo, the following notes regarding the general and economic geology of that part of the island were made. I was assisted in the field by Mr. Percy Kincaid, formerly of the Bureau of Science, and was furnished survey notes by Mr. R. L. Moore, of the Bureau of Lands.

GENERAL STATEMENT

A description of the general geographic features of the Island of Panay based on Abella's work[3] follows. Panay, which because of its size, richness, and population is the most important island of the Philippines after Luzon, is situated among the Visayans precisely in the center of the Archipelago and is found comprehended between the latitudes 10° 24′ 37″ and 11° 55′ 57″ north and between the longitudes 125° 30′ 16″ and 126° 50′ 24″ east of Madrid (121° 50′ and 123° 20′ east of Greenwich).

Panay has roughly a triangular shape. The greatest lengths which can be taken from north to south and from east to west, respectively, are 168 and 119 kilometers. The total area of the island is 11,580 square kilometers, of which 4,547 apply to the district of Capiz, 2,472 to that of Antique, and 4,561 to that of Iloilo. The population of Panay consists almost entirely of Visa-

[3] An unpublished translation of this important Spanish document was made by Mr. McCaskey, formerly chief of the division of mines of the Bureau of Science. This translation is on file in the library of the Bureau of Science, Manila.

yans, and their number amounted to 775,202 according to the census of 1903. The temperature, rainfall, and vegetation conditions of Panay are very much like those of the Island of Cebu.

One cordillera runs almost from north to south separating the Province of Antique from the Provinces of Capiz and Iloilo. This cordillera lies much nearer to the western coast than to the eastern and follows a sinuous course starting in the extreme northwest corner of the island, winding eastward, and then swinging back to the southwest corner. In the northeastern part of the island there is a mountainous cluster, but no true cordillera exists. Between these two is considerable flat country, but a little north of the center of the island is a highland tract connecting the western cordillera and the eastern mountains. Owing to the necessary vertical exaggeration in the relief map (Plate I), the true physiography of the central plain does not appear in the photograph. North and south of this divide there is low country. The largest tract of plain country is comprised of what is called the Iloilo plain, the lower part of which is chiefly a delta. The largest streams of the island start on the eastern slope of the cordillera and run east or north of this and then turn to the south and meander across the Iloilo plain. The slopes on the western side of the cordillera are much more precipitous, and the streams there are short and swift. Abella's report gives detailed descriptions of the various mountain passes, the drainage in Panay, and profiles showing the general character of the skyline in various parts of the island.

PHYSIOGRAPHY

In Abella's report there is little mention made of the physiographic and geologic factors underlying the principal characteristics of the country. The relation of topography to geology and the human response to these material factors have been shown in many parts of the world, but very little has been written on this subject in its relation to the Philippine Islands. First, I wish to draw attention to the effect of the geology upon the topography. The dominant rocks in Panay—that is, in the habitable portion—are Tertiary sedimentaries—clays, sandstones, shales, limestones, and conglomerates. We find these lying blanketlike over parts of the Iloilo plain and extending up the sides of the cordillera. In the lower part of the streams rising in the cordillera we find the course of the streams at right angles to the strike of the formation—that is, in the direction of the dip. As we go up these streams, we find tributaries

coming in on both sides or joining the main stream along lines corresponding to the strike of the formation. For some distances the main streams themselves follow the strike, but as a rule they cut nearly at right angles to it. The geologic structure is reflected in the topographic aspect of the country and is characteristic of block mountains. As we look upstream from the lower courses, we see long gentle slopes; but when we ascend and look backward, we are confronted by abrupt slopes due to the upturned edges of the formation. The conditions may be represented by the diagram as seen in fig. 1.

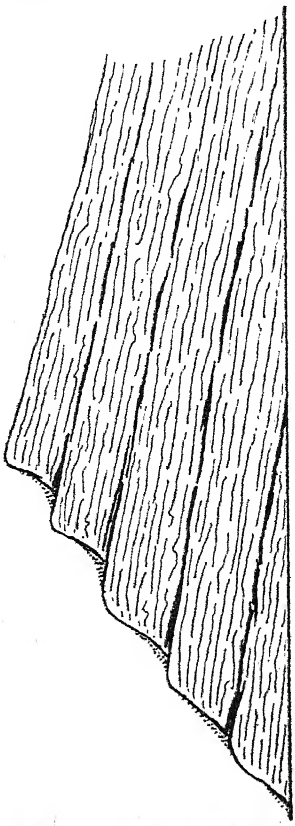


Fig. 1. Character of topography in tilted sedimentaries.

Where the rocks are hard, the streams cut through in narrow gorges, but where the formations are soft, as in the shales and some of the soft limestone, the country is open and the streams run in wide valleys. There are many places in Panay where one encounters box cañons, which at the time of high water are very difficult to pass through. These are usually in the hard resistant conglomerate. Many of these would afford excellent dam sites. Where the streams have cut back into the harder rock, such as volcanic agglomerates and diorite, there is no system to their course. They seem to follow no particular lines, save possibly here and there the jointing has exerted a local influence. When the low country is reached, the streams take their own courses again and meander irregularly over the broad plains.

DISTRIBUTION OF THE PEOPLE

In the report of the Philippine Census of 1903 there is a general map showing the distribution of the various tribes of the Islands, and the map of Panay, as shown in fig. 2, is reproduced from this. Following the cordillera and the tongue of highland, cut-

ting across the north-central part of the island, and thence into the mountain cluster to the northeast, there is an area occupied by Bukidnons (people of the mountains). They occupy the same relative position to the people of the low country as do the mountaineers of eastern Tennessee and North Carolina to the people of the Piedmont Plateau. They comprise, for the most part, Visayans who have been pushed back into the mountains for

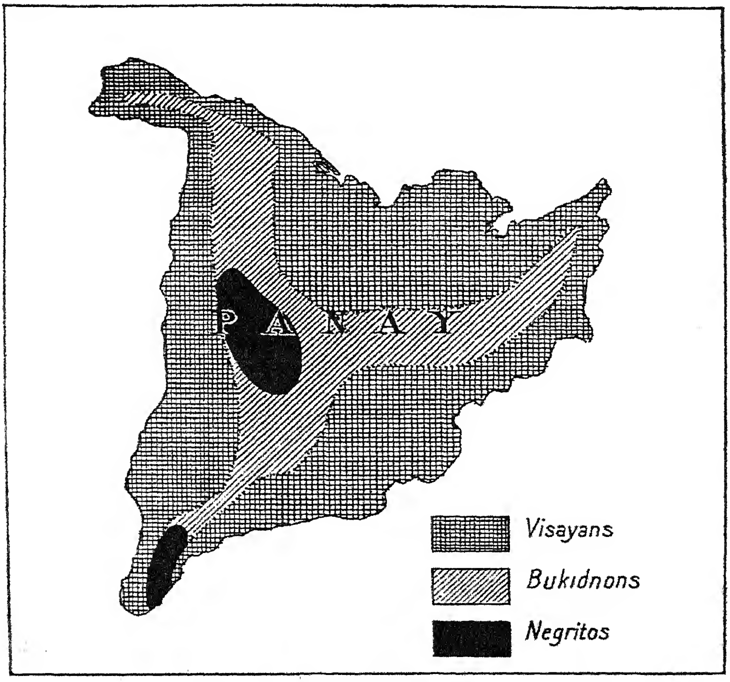


FIG. 2. Distribution of tribes in Panay.

one cause or another, their language becoming somewhat modified. At two points along the crest of the cordillera, the one in the extreme south and the other in the center of the cordillera, in the almost inaccessible region of Mount Baloy, there are two small areas said to be occupied by Negritos, the original inhabitants of the Philippines.

We have here then an excellent example of the influence of topography and geology upon the distribution of the peoples. These three groups, Negritos, Bukidnons, and Visayans, are

sharply defined, and their distribution is controlled strictly by geologic and topographical factors. Where the rocks are hardest and most denuded of soil, where the topography is the most rugged, where existence is the most difficult, there one finds the most primitive peoples. Now that there is a railroad running from north to south connecting the cities of the Provinces of Capiz and Iloilo, we shall see the territory of the Bukidnon people penetrated, and gradually their range will be more and more restricted.

Even among the lowland peoples of Panay there is a considerable variation in the dialects. The Filipino is, as a rule, a home-loving individual, who does not care to travel far from his friends. It is always difficult to get packers to go with one into the high mountains and into territory that is unknown to them, and all this tends to retard the dispersion of isolated groups and the free interchange of ideas and commodities.

VEGETATION

There is remarkably little forest anywhere on this island with the exception of a small area in the central portion of the cordillera. In this respect Panay resembles Cebu. The extreme deforestation is due to the *caiñgin* system, which consists in clearing and burning the forest on a small tract of land, the raising of one crop on the hilly soil, then the abandonment of this tract for a new location. The inhabitants of the high country, in Panay, at least, very rarely raise two crops in succession on the same piece of ground. The encroachment of cogon grass on the deforested area prevents the growth of a new forest and makes the land unsuitable for tillage. It is easier to clear a new spot than to prepare and open the field for crops on the old ground. This ruthless system is now having its effects on the country. Without the retaining powers of the forest and undergrowth the rainfall rapidly runs off, eroding the country and carrying enormous volumes of gravel and silt into the bottom land. This is the chief cause of the great devastation wrought by the streams in this and other parts of the Philippines. The sudden rising of these mountain streams and their pouring out onto the plain cause great floods, ruin crops, and destroy bridges, resulting in the rapid silting up of river beds and filling up of navigable streams, and the formations of bars where once existed open channels. China to-day pays a terrible annual toll in lives and money as a result of the practice of the same system in the past. There is scarcely a stick of

wood left on her mountains, and the Philippines would soon be in the same plight but for the Government's timely forest conservation policy.

GENERAL GEOLOGY

As already pointed out by Abella, the general classes of rocks found on Panay are: The recent formations of the plains; the Tertiary limestone, shales, and sandstone in the foothills; the core of igneous rocks in the cordillera; and some doubtful rocks, approaching slates, which come between the igneous formations and the Tertiary series.

The best development of sedimentaries I have yet seen in the Philippines exists on Panay, and the best sections for studying them are perhaps to be found there. On Suague River Mr. Pratt estimated that the total thickness of the Tertiary series amounts to more than 9,000 meters, and if we include the older series of "slaty" rocks at the headwaters of Ulion River the total will be about 10,000 meters. I found very much the same series on Tigum River, the two streams being roughly parallel and only a few miles apart. A short distance above the barrio of Tinayoc Tigum River has cut into the hillside, affording an excellent section, which is typical, as follows:

	Meters.
Thin-bedded sandy shale	15–20
Heavy-bedded sandstone	5
Sandstone	$\frac{1}{2}$
Carbonaceous shale	$\frac{3}{4}$
Sandstone	$\frac{1}{2}$
Carbonaceous shale, less than	$\frac{1}{3}$
Heavy-bedded sandstone	5
Thin-bedded sandstone and shale	16
Heavy-bedded sandstone at base	

The dip at this point is 30° to the southeast, and the strike is north 10° east. Descriptions of three different samples of the sandstone follow:

Sample 2312.—Buff to gray, very coarse, and apparently made up of triturated particles from various kinds of igneous rocks occurring in the cordillera. There is little quartz in the specimen, but fragments of ferromagnesian minerals predominate. The buff color is largely due to fragments of olivine washed out of the decomposing picrites known to occur in the cordillera. This rock has a porosity of only 5.5 per cent, the voids being filled largely with iron oxide and calcium carbonate as a cementing material.

Sample 2313.—This sample is a much finer and more even-grained grayish rock with much the same mineral composition as sample 2312. The porosity of this specimen is greater.

Sample 2314.—This sample is a still finer grained rock with more of the characters of a shale than of a sandstone.

In the same series of sediments with these sandstone beds are several layers of conglomerate, conformable and of varying thickness. These conglomerates consist of many kinds of pebbles in a firmly cemented, sandy matrix. At one place I noted pebbles and fragments of the following kinds of rocks:

1. Limestone with coral remains.
2. Andesite—3 or 4 varieties.
3. Amygdaloid.
4. Shale.
5. Rock resembling jasper, but which is probably rhyolite, as it appears to have quartz phenocrysts.
6. Diorite—coarse-grained.
7. Diorite—fine-grained.
8. Picrite—a rock rich in olivine.
9. Quartz.

Occasionally fossil shells are found, one of which is presumably *Vicarya callosa* Jenk. Hence the age of these beds is that of the Lower Miocene, or the same age as the Cebu coal measures. Fuller descriptions of these sedimentaries are given by Abella.

The shales.—The shales exposed in the lower reaches of the streams flowing from the cordillera are thin-bedded and grayish to bluish, and resemble other Tertiary shales in many parts of the Philippines, the type example of which is the Vigo series on Bondoc Peninsula, Tayabas, Luzon.[4] These shales have practically the same mineral composition as the sandstone, the chief difference being in grain size. In the upper part of Tigum River the shales are yellowish, but lower down, where we first discovered them, they are bluish. In the survey of Tigum River we found that there are at least 5,000 meters of these shales exposed from the point where the survey began to the first considerable thickness of sandstone. Of course, there are occasional thin beds of sandstone in this series, but they are negligible. Several wells have been drilled by the Bureau of Public Works in these shales in the hope of obtaining artesian water, but they have been generally unsuccessful.

[4] Cf. Pratt, W. E., and Smith, W. D., *This Journal, Sec. A* (1913), 8, 331.

Log of Well No. 161, Iloilo, Iloilo.

Depth in feet.	Strata.	
	Drillers' classification.	Remarks.
0- 80	Shale with numerous shale fragments and small gravel.	
80- 90	Finer shale, slightly calcareous	
90- 100	Dark shale, not calcareous	Fine quartz fragments; resembles loam.
100- 110	Adobe—heavy clay material	Result of disintegration of basic rock.
110- 130	Gray calcareous shale	
130- 150	Same as 90 to 100 feet	Finer grained.
150- 170	do	Do.
170- 190	Adobe	
190- 210	Gray shale, not calcareous	
210- 300	Shale, slightly calcareous	
300- 400	Shale, strongly calcareous	
400- 500	Fine-grained shale	Similar to previous strata.
500- 600	Shale	
600- 650	Shale, strongly calcareous	
650- 675	Sand, very fine but fairly clean	
675- 710	Adobe	
710- 800	Sand, but not so good as from 650 to 675 feet	
800- 910	Adobe	
910- 920	Shale, slightly calcareous	
920- 975	do	Much the same as from 910 to 920 feet.
975-1,100	Marl	
1,100-2,285	Fine-grained marl	

A discussion of the ground-water resources will be found on page 226. A noteworthy point in connection with the wells sunk in these shales is that the water obtained was salty. Mr. Pratt in his manuscript report has given the following satisfactory explanation of the brackishness of the water:

If one accepts the most probable explanation of the presence of salt and other minerals in the upper clay and shale, i. e., that they came from the sea water in which the beds formed and are, consequently, original constituents of the series, it is clear that the effect of ground waters, active since the elevation of the land above sea level, would be a leaching out of the soluble salts.

I see no reason for thinking that the salt water has come from the sea. Any flow of water depends upon head, and the flow normally is from the land into the sea rather than vice versa.

Rapidly changing conditions of sedimentation must have existed throughout the formation of these beds. The thinness of certain beds, the repeated alternation in character of the

Well No. 308, Janiuay, Iloilo.

Depth in meters.	Strata.	
	Drillers' classification.	Remarks.
0– 5	Gravel and clay	
5– 10	Bowlders and clay	
10– 15	Gumbo clay	Gumbo clay is probably a stiff dark-colored clay.
15– 20	Black sticky clay	
20– 35	Joint clay	Joint clay is applied to the blue clay of the upper clay and shale series of this record.
35– 37	Blue sticky clay	
37– 41	Blue sandy clay and gravel	
41– 43	Clay and gravel	
43– 55	Blue sandy clay and joint clay	Alluvial to 43 meters. Upper clay and shale below 55 meters.
55–124	Joint clay	
124–147	Clay and loose stone	"Loose stone" is probably applied to calcareous concretions which are known to occur in the blue clay.
147–169	Joint clay	
169–175	Joint clay and loose stone	
175–187	Joint clay	
187–199	Volcanic	"Volcanic"—possibly a silt which was mistaken for volcanic tuff. The drill penetrated it 12 meters in 9 hours.
199–207	Quick clay	
207–247	Joint clay and loose stone	
247–266	Joint clay	
266–273	Joint clay and loose stone	
273–315	Joint clay	
315–320	Joint clay and loose stone	
320–348	Fine sand and gravel	
348–360	Joint clay and loose stone	
360–428	Joint clay	
428–468	Brown sand and clay	
468–490	Joint clay	
490–493	Shale	
493–506	Rock	Rock, calcareous shale.
506–527	Clay bowlders and quicksand	Clay bowlders.
527–531	Shale mixed with fine black sand	Sand from strata above mixed with shale.
531–537	Sand, gas, and salt water	

sediments, cross-bedding, and other factors all indicate that there were either repeated oscillations of level or rapidly succeeding freshets, or both. It is important to note that the conditions are unfavorable for the formation of coal deposits of economic size. The only coal seams seen by me were not over 5 centimeters thick.

STRUCTURE

The Tertiary series of shales and sandstones described above overlap the igneous core of the cordillera and constitute a great monocline dipping eastward toward the Iloilo plain. Near the

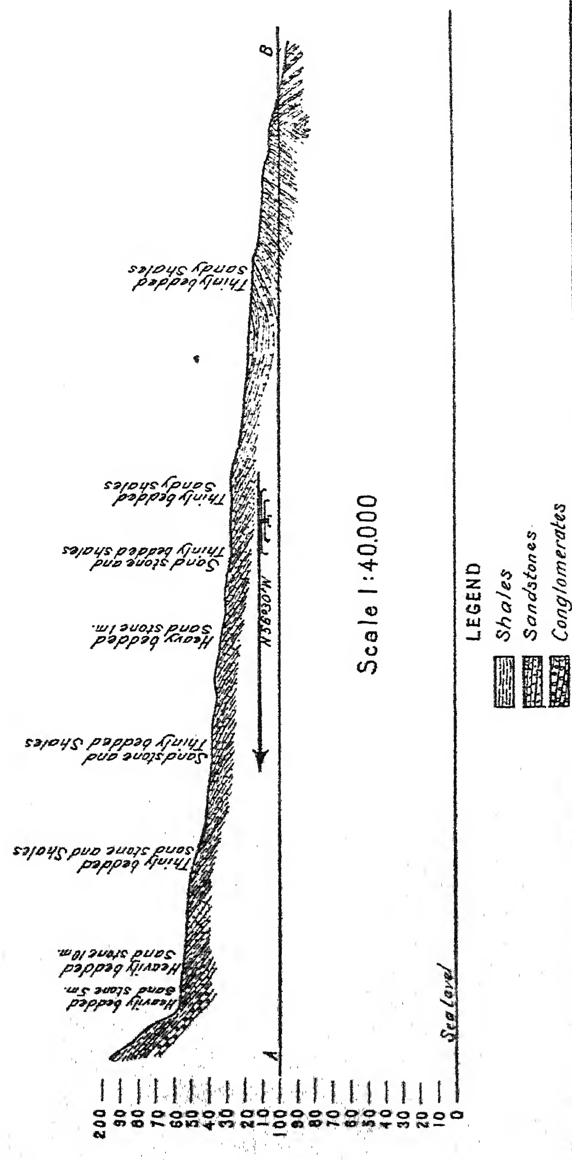


FIG. 3. Geologic section across Iloilo Province, Panay. After Abella.

cordillera the dip of the beds is as high as 70°, but gradually this inclination decreases till the beds assume an almost horizontal position. The inclination of the beds is much greater on the Antique (west) side of the cordillera. In the foothills local undulations with reverse dips attended by some faulting are to be noted (fig. 3).

As pointed out in the discussion of the control of topography, these strata assume the attitude of tilted blocks with the abrupt slope up- and the gentler slope downstream, this slope in most cases corresponding exactly to the bedding planes. Abella's profiles are very good representations of the general conditions. A somewhat modified section, using Abella as a basis, is shown in fig. 3. The survey of Tigum River has revealed the existence of a small anticline just east of Maasin, and perhaps many others exist which would be revealed by a detailed survey of the region. These anticlines are all important in the matter of the accumulation of oil. Complete folds in the strata are, however, the exception, and the dominating structure is monoclinal. Of course, where there are anticlines the reverse type of fold, the syncline, must exist. There is one of these shown in fig. 3 just west of the Maasin anticline. As anticlines usually afford the most favorable places for the accumulation of oil, artesian waters are most favorably tapped in the synclines. The reason for this marked difference between two mobile substances is due to their difference in specific gravity. For further discussion of the petroleum possibilities in this region see page 225.

PRE-TERTIARY FORMATIONS

At an elevation of about 400 meters near the headwaters of Ulion River there is an excellent exposure of indurated sediments closely resembling slate. Intercalated with these are sills of diorite from 3 to 5 meters thick. The sills follow the bedding planes. The strike of these slaty sediments is northwest, and the dip is 30° to the northeast. No marked difference was noted between that part of the sedimentary beds nearest the sills and the interior; so it is improbable that the hard slaty character of these beds can be due entirely to the heat or pressure resulting from the intrusion of the sills.

Specimen 2322.—The rock is blue-black, very dense, exceedingly fine-grained, and has a hackly to conchoidal fracture. It shows on certain surfaces a very fine banding which is distinctly that of sedimentation. The cleavage in these beds is not typical of slates, and hence they might more properly be termed pseudoslates.

Microscopic.—The thin section of this rock is difficult to study owing to the flakes of iron oxide and numerous dark fragments which cannot be easily identified because of their amorphous condition. Fragments of quartz, feldspar, and ferromagnesian minerals are abundant. The whole aspect of the section is that of a clastic rock. Numerous fragments of globigerines and of radiolarian tests are to be seen, but neither the species nor the genera can be distinguished. This rock probably corresponds to the "clay slates" mentioned by Molengraaff [5] in his descriptions of certain rocks collected in central Borneo. He gives the following description of certain rocks encountered on Poelau Lolong River:

> The country at this point and higher upstream consists of a system of highly folded strata. The strike may be averaged at about E.-W. and E. N. E., but both strike and dip vary considerably. The strata as a rule are highly inclined and not seldom stand vertical. The oldest group in this complex is composed of clay-slate, chert, hornstone, sandstone, diabase, diabase-tuff, and diabase-tuff-breccia, also gabbro and serpentine, the latter being derived partly from a variety of olivine-norite * * * partly from picrite or from hartzburgite. * * * Some of the diabases * * * form intrusive masses, sheets, or dikes in the sedimentary formations and are therefore younger than these. * * * The cherts are sometimes full of biotite and then resemble silicified micaceous clay-slate, at other times they turn to pure jasper and hornstone. The hornstone is sometimes of a milky white colour, often marbled and alternating with bright red jasper. The chert, and particularly the jasper and pure hornstone, contain Radiolaria and are often almost entirely composed of the tests of these organisms. In the jasper, the Radiolaria can be detected with an ordinary pocket lens, and they look like so many round specks, or little grease spots the size of a pin's head. This greasy lustre is caused by the tests of the Radiolaria being filled with an aggregate of quartz which is coarser than the cryptocrystalline composition of the jasper itself. As mentioned before (page 92) these cherts with Radiolaria are of pre-Cretaceous age.

This also describes fairly accurately what we found on the headwaters of Ulion River. Just what the exact relationships are in this rather confused group of rocks has not yet been determined, but the fact that we have rocks practically identical with those of central Borneo and that they are considered to be older than the Tertiary is very important.[6]

Near the source of Ulion River I found an outcrop of jasper, the position of which was not very clear. In thin sections this proved to be similar to the rock I had described from Ilocos Norte in 1906.[7]

[5] Geolog. Explorations in Central Borneo. Amsterdam (1902), 174.

[6] Molengraaff, op. cit., 174.

[7] *This Journal, Sec. A* (1907), 2, 145.

Sample 2323, macroscopic.—The rock is pinkish with occasional fine black streaks in it, rather fine-grained, and fissile, so that it breaks into more or less thin slabs.

Microscopic.—The groundmass consists of cryptocrystalline silica, dotted with small roundish and oval areas filled with small irregular grains of silica but little larger than those constituting the groundmass. These roundish areas undoubtedly represent tests of Radiolaria, but nothing now remains save the cast.

In another sample tests of Radiolaria belonging to the following three genera were identified: *Stylosphæra, Dictyomitra,* and *Cenosphæra.* The species of the first-named could not be told, but under the second, the species *affinis* was distinguished without difficulty, and of the third genus, which is by far the commonest, the species *minuta* and *disseminata* were recognized.

We have now found this radiolarian chert in Ilocos Norte and Bulacan, Luzon, in Panay Island, and in Balabac Island—from the northernmost to the southernmost part of the Archipelago. Outside the Philippines the same rocks are known to occur in the Moluccas,[8] in the Federated Malay States,[9] and in California,[10] and everywhere they are referred to the Jurassic. We have every reason then to believe that this formation, or group of strata, in the Philippines is distinctly older than the Tertiary.

Associated with these red rocks are some green rocks, which in a thin section are shown to be serpentine, and these, we have seen, accompany the cherts of central Borneo.

IGNEOUS ROCKS

As Abella has devoted no little space to the igneous rocks which he found in the cordillera, I shall not discuss them at length. His list includes the following:

1. Andesite.
2. Basalt.
3. Diabase.
4. Diorite.
5. Diorite (quartz).
6. Gabbro.
7. Picrite.
8. Serpentine.
9. Tonalite.
10. Trachyte.

Of these the different varieties of andesite constitute the dominant rocks of the cordillera, and similar rocks have been described in Philippine literature. Of the rest we need call attention only to the tonalite and the picrite. We have found

[8] Martin, R., Reisen in den Molukken. Geolog. Theil. 2te Lief., 171.

[9] Scrivenor, J. B., Geol. Mag. (1912), 9, 241–48.

[10] Fairbanks, H. W., *Journ. Geol.* (1895), 3, 418.

these quartz-mica-hornblende-diorites in various parts of the Philippines, but they are not common.

As the picrites are still more uncommon, I shall give Abella's own description of them:

> The *picrites* have a beautiful emerald green color with bronze metallic reflections of a crystalline texture, and in them is seen olivine, augite, and bronze hypersthene, a white mass being distinguished among these crystals, semigranular, almost pulverulent, which at some time might have originated from a preëxisting feldspar or nepheline, which cannot now be classified as such, nor give, therefore, character to the rock. Under the microscope this white mass resolves itself into a whitish magma, amorphous and decomposed, which in the polarized light emits, notwithstanding, certain pale gray bluish and yellowish colorizations, all of which confirms the supposition attributing to it the feldspathic and nephelinic origin, * * *.
>
> Based on these characters and on the almost holocrystalline texture which the three elements of this rock display, we shall classify it as peridotic, and designate it as picrite.

The western cordillera certainly affords an interesting field for the petrographer, and its thorough exploration may some day reveal deposits of great commercial value. For instance, the "picrites" which Abella mentions are about the most basic rocks known, and in their vicinity it is reasonable to expect that valuable deposits of metals will be found.

ECONOMIC GEOLOGY

In the third part of his report Abella discusses the occurrences of various nonmetals and metals. Since Abella's time a slight amount of prospecting has been carried on in Antique Province by Americans, with the result that promising deposits of chromic iron and copper have been reported, but nothing of value has been found on the eastern side of the cordillera. The presence of petroleum and coal has also been reported. Specimens of wolframite have been sent to the Bureau of Science by two persons from Antique Province, who, however, gave no definite information with regard to them. If there is any considerable quantity, it will be valuable. Serpentine containing asbestiform minerals has also been noted in the same province.

The presence of petroleum at Janiuay, Iloilo Province, was reported many years ago, but during a recent reconnaissance of the province, I failed to see any oil. However, at Janiuay I visited a well 537 meters in depth, which was bored nearly two years before by the Bureau of Public Works for artesian water, and which was emitting gas and salt water intermittently. This may be an indication of the presence of petroleum at a lower

horizon. That this is not simply marsh gas is, I believe, shown by the analysis.

Analysis of the gas collected by Wallace E. Pratt[a] *from the Janiuay well in 1912.*[b]

	Per cent.
Hydrogen	5.2
Methane	89.4
Ethane	0.0
Carbon dioxide	0.6
Nitrogen	4.3
Oxygen	0.0
Carbon monoxide	0.5

[a] *Mineral Resources P. I. for 1912* (1913), 47.
[b] Analysis by Forrest B. Beyer, chemist, Bureau of Science.

It is known, of course, that methane is the chief constituent of natural gas and that ethane is usually found in it, but examples are known where the latter is absent. The presence of hydrogen and of nitrogen particularly seems to argue in favor of the supposition that this gas is not merely a product of vegetable decay. It is not impossible, of course, to have a marsh deposit at almost any depth in sedimentary formations. The facts, however, that we have some considerable depth, presence of salt water, and these extra constituents seem to make it highly probable that this is natural gas and is associated with a deposit of petroleum. As to the amount of oil likely to be present in these formations we can only conjecture.

As traverses were made along the streams in this part of the island, close watch was kept for any oil seeps, but nothing was seen even suggestive of the presence of oil. It is possible, of course, that the oil is of so light a grade that on evaporation it leaves no residue easily detected on the rocks and thus would easily be overlooked.

The sedimentary formations are so folded that what oil may be present would be collected into natural reservoirs. There are indications also that sandy beds exist which would afford sufficient pore space for the retention of any oil that may be present. For these reasons we can say that it is not at all unlikely that petroleum does exist in this island.

GROUND-WATER RESOURCES

The importance of an adequate supply of pure water in tropical countries no longer needs any argument. The need for a supply of uncontaminated water for the growing city of Iloilo has become pressing. Several unsuccessful deep wells have been

bored at Iloilo and in the neighboring towns. One well at Iloilo penetrated to a depth of about 800 meters in clays, sands, and shales and struck no potable water. The well at Janiuay already mentioned did not get through the thin-bedded shales and resulted only in striking salt water and gas. A number of comparatively shallow wells near Iloilo which did not go below the alluvium obtained water which in some cases proved to be brackish and in others to have a taste of iron. After these unsuccessful attempts were made, a scheme for diverting water from Tigum River into a reservoir from which it was to be piped a long distance to Iloilo was projected. This, however, would entail the expenditure of at least a million pesos, and naturally there was some hesitation about undertaking it. Finally I was detailed to visit the region with instructions to look into the artesian-well possibilities. After three weeks on the ground I submitted a report giving the following conclusions:

1. The artesian conditions of the sandstones and conglomerates are not sufficiently favorable for us to recommend any further expenditure of money in this direction.

2. It is deemed probable that an adequate water supply can be obtained from the deep gravels in the alluvial deposits in the lower end of the Iloilo plain.

3. More detailed study of this region should be made along the lines adopted by the hydrographic branch of the United States Geological Survey.

4. Geologic investigation should precede all artesian-well projects.

The first conclusion was arrived at after due consideration of the depth, inclination, thickness, and porosity of the possible water-bearing strata, all of which appeared as pointing to very unfavorable conditions, and in view of the past experience in this district in well-boring, other and simpler means of getting water should be tried first.

Since this investigation was made, reports from that locality state that in some of the wells near Iloilo, particularly the one at Molo, the water has improved and is losing some of its brackish taste. In one of these wells I noted a slight taste of iron, which would not be harmful and even might be beneficial. It is my expectation that the water from these wells will in time become entirely potable, and that sufficient water for the supply of the city of Iloilo will be obtained from numerous comparatively shallow (75 to 300 meters) wells in the ancient gravels of this plain.

SEISMIC GEOLOGY

The seismic disturbances in this island have been discussed already.[11] It seems reasonably certain that the majority of the disturbances which have occurred there are local and are of the rockfall type. I have seen some landslips which have resulted from the slipping of the sediments, particularly the shales, over one another along bedding planes. If these are large enough, they can easily set up vibrations which would be recorded by seismographs.

Other disturbances have been of greater intensity and were due to displacements along the line of contact between the sediments on the western side of Guimaras Island and the igneous formation on the east.

It is possible, also, that other differential movements have taken place between the valley alluvium and the mountain mass, which would give rise to seismic disturbances.

There is no evidence as far as I know of vulcanism on the island since the Pleistocene, at least, to which we could attribute any of these disturbances. Whatever their origin, they have been of minor importance, and Panay is now one of the most stable parts of the Archipelago.

SUMMARY AND CONCLUSIONS

The relation of geology to the topography and indirectly the bearing it has upon the distribution and activities of the people has been shown.

The vegetation of the country shows the devastating effects of the caiñgin system, and the effect of this upon the economic welfare of the people has been indicated.

The existence of a hitherto suspected but unverified new-old formation, almost certainly Jurassic in age, has been proved.

Attention has been called to new prospects in mining and the favorable geologic features connected therewith. Deeper drilling for oil in the vicinity of Janiuay is recommended.

The ground-water resources of a portion of the island have been touched upon, and the possibility of utilizing the water contained in the ancient buried gravels of the Iloilo plain has been pointed out.

Attention has been called to the seismic geology. Panay is one of the most stable parts of the Archipelago, and the majority of the few earthquakes occurring on the island are due to rockfall and hence are local.

[11] Saderra Maso, Miguel, and Smith, W. D., *This Journal, Sec. A* (1913), **8**, 199.

ILLUSTRATIONS

TEXT FIGURES

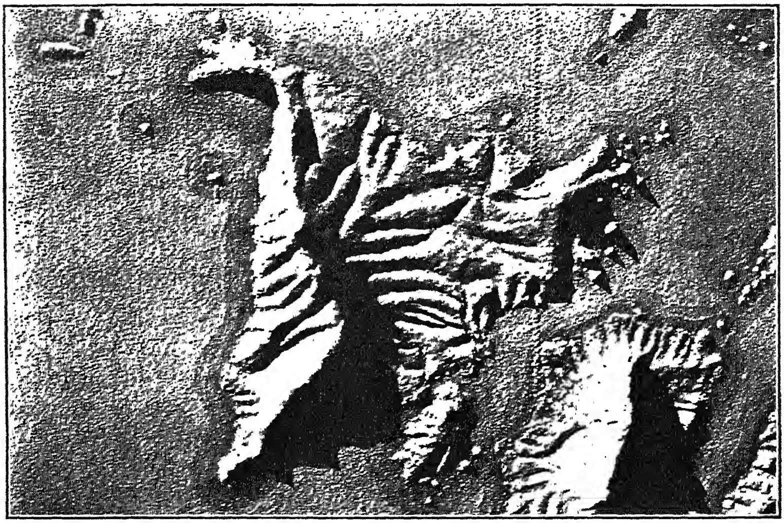


PLATE I. PHOTOGRAPH OF A RELIEF MAP OF PANAY.

THE PHILIPPINE

JOURNAL OF SCIENCE

A. CHEMICAL AND GEOLOGICAL SCIENCES
AND THE INDUSTRIES

VOL. X JULY, 1915 No. 4

THE LOCATION OF ARTESIAN WELLS IN THE PHILIPPINE ISLANDS FROM A GEOLOGIC VIEWPOINT[1]

By WALLACE E. PRATT

(From the Division of Mines, Bureau of Science, Manila, P. I.)

It will be assumed that the reader is conversant with the principles governing the phenomena of artesian wells, and in the following discussion no attempt will be made to consider the numerous factors which control the subsurface accumulation of water under hydrostatic conditions.

The conditions under which water-bearing rocks, like intercalated sandstones and shales, were laid down in the Philippines, where the distribution of land masses is irregular and the interruption of sedimentary processes by vulcanism was frequent, were so variable that no single bed nor any series of beds extends uniformly over great distances. Thus it is not possible here, as it is, for instance, in Australia, to map closely the outcrop of the " intake beds" nor to calculate the depths at which such beds will be encountered over large areas.

It is probable that very often wells will be drilled at towns which need most urgently a supply of potable water, irrespective of the chances of obtaining water. Frequently there will be little choice between different possible locations in a small town, and it may be found expedient to locate the well on the plaza or at some other central point without taking into consideration any other controlling factors. However, where towns are so situated as to include within their area parts of different geologic formations, there may be opportunity to exercise some discretion in choosing a drilling site.

[1] Received for publication May 28, 1915.

A large proportion of the flowing wells in the Philippines will cease to flow if the casing is continued even a few meters above the ground surface; that is to say, if such wells had been drilled from a slightly higher elevation, it would have been necessary to pump them. It follows that, other things being equal, the lower of two possible sites is preferable. However, the possibility of surface contamination should be kept in mind in this connection. A well on low ground is more often contaminated by surface waters than one on higher ground. It is true also that a well should not be located too near the seashore in an attempt to get it on low ground. Too often in such a location the well encounters brackish water.

Through the coöperation of the Bureau of Public Works the Bureau of Science has had access to drillers' logs for about 700 artesian wells. Samples of the drill cuttings have been submitted for examination in the cases of about half of these wells. These data, and a knowledge of the general geology of the Philippines, are made the basis of the following discussion.

For their consideration in relation to artesian waters the geologic formations of the Philippines may be classed and summarized as shown in Table I.

LITTORAL AND ALLUVIAL DEPOSITS

A large proportion of the population of the Philippines lives in regions in which the land is made up of littoral and alluvial deposits. The important areas of alluvium are found in great structural valleys like the Central Plain of Luzon, the Cagayan Valley in northern Luzon, the Bicol Valley in southeastern Luzon, the Iloilo Plain in Panay, and the Cotabato and Agusan Valleys in Mindanao. The littoral deposits make up the coastal plains which fringe many of the islands, like the plain upon which the town of Cebu is located. The structural valleys have been filled up by loose clays, sands, and gravels carried down from the adjacent highlands by shifting streams and deposited along an ever-advancing shore line. The coastal plains have been built up in the same way; in many cases they rest upon a base of coral reefs, which have grown up offshore from the various land masses. Both the filled structural valleys and the coastal plains combine alluvial and littoral deposits in their structure, since the alluvium carried by streams was deposited largely at the seashore where part of it was worked over again by wave action. In either situation the littoral and alluvial deposits are surprisingly thick; in very few cases have wells passed through them into the underlying formations.

TABLE I.—*Geologic formations in the Philippines and their relation to artesian-water supplies.*

Formation.	Extent of formation and degree to which it is populated.	Distribution of formation.	Character as a source of artesian water.
Littoral and alluvial deposits	Extensive and densely populated; therefore, important.	Seacoast and low-lying plains; all coastal plains: Central Plain, Cagayan Valley, Bicol Valley, on Luzon; Iloilo Plain, Panay; Agusan and Cotabato Valleys, Mindanao, etc.	Good; a majority of shallow wells in it are successful; source of most of artesian water now obtained, but many unsuccessful wells have been drilled in it.
Coralline limestone	Extensive and densely populated in the Visayans; fairly important.	Seacoast: Cebu, Samar, Bohol, Negros, etc.	Fair only; many wells are dry, some salty.
Volcanic breccia and agglomerates	Fairly extensive, but only fairly well populated.	Mountainous and high plateau areas throughout the Islands.	Fair only in general; some types are commonly water-bearing.
Bedded volcanic tuff	Fairly extensive; densely populated	Southwestern Luzon	Very good; some of the best wells obtain water from this formation.
Tertiary sedimentaries	Extensive; fairly well populated only	Interior and mountainous regions; coal- and petroleum-bearing regions generally; Samar.	Bad; dry formation full of salt.
Massive igneous rocks	Extensive, but not usually densely populated.	Interior and mountainous regions generally.	Very bad.
Metamorphic rocks	Limited extent and sparsely populated; unimportant.	Interior and mountainous regions	Bad.

A majority of the wells drilled by the Bureau of Public Works have penetrated these classes of material. A majority also of the successful wells have obtained their water from sands and gravels of littoral or alluvial or combined littoral and alluvial origin. It cannot be said, however, that littoral and alluvial deposits are uniformly productive of artesian water. Such deposits are irregular, and individual beds do not extend over large areas. On the contrary, the formation is characterized by narrow lenses of sand or gravel or clay, such as would be expected in the beds of modern streams or along beaches. It is due to this feature of littoral and alluvial deposits that so often a flowing well will be secured adjacent to a drilled hole which has obtained no water or only pumping water. A striking example is the case of two wells drilled within 50 meters of each other between the Philippine General Hospital and the Bureau of Science in Manila. The first well reached a depth of 178 meters and obtained only 113 liters of water per minute. The second well obtained 322 liters per minute at a depth of only 137 meters. On the completion of the second well work was resumed on the first well in an attempt to get water at the 137-meter horizon, but all efforts to this end failed. Neither of these wells flowed, but numerous experiments have demonstrated that in this class of deposits flowing wells, nonflowing wells, and dry wells may be situated side by side.

As has been said, littoral and alluvial deposits are made up of loosely consolidated sands, clays, and gravels. The loose character of the formation is responsible for the commonly noted phenomenon that in wells situated near the coast line the level of the water in the well varies with the stage of the tide in the adjacent sea. The fresh water in the upper part of the land mass is always percolating through porous beds toward the sea, and in the region of the seashore it is in some measure in a condition of hydrostatic equilibrium with the sea water, which saturates the porous beds outcropping on the sea floor. The rising tide actually increases the hydrostatic pressure on the ground water in the adjacent porous beds. This effect is especially marked where an old coral reef has been included between the deeper beds of the formation, because the loose structure of the coral reef affords unusually free passage for water.

Another factor which must be considered in connection with littoral and alluvial formations is the possibility of obtaining salt water in wells adjacent to the coast. Littoral deposits are contaminated by the salt water in which they were formed. Close to the coast line percolation of the fresh ground water

may not have been extensive enough to have removed all the original salt, particularly where the formation contains clay, which is not easily permeable. Salt water is almost inevitably encountered at depth in wells near the coast line. The ground-water circulation appears to be most vigorous at depths generally less than 180 meters. Consequently, if potable water is encountered in littoral or alluvial deposits at depths of from 60 to 150 meters, it is usually advisable to make arrangements to use this water even though it be of limited quantity and require pumping, rather than to continue drilling in the hope of obtaining flowing water or water in greater quantity at extreme depths. Occasionally, where it has been possible to case out salt water, wells have been deepened and have obtained fresh water at lower levels, but as a rule, fresh water has not been found below salt water.

The discussion of alluvial and littoral deposits and combinations of these two classes of deposits may be extended and applied to intermingled alluvial, littoral, and fragmental volcanic material as well. Volcanic tuffs are often and extensively interbedded with alluvium and with littoral deposits in the Philippines; less frequently volcanic breccias and agglomerates alternate with alluvial or littoral material. Volcanic tuffs, as a matter of fact, usually contain interbedded alluvium, and similarly alluvium usually includes some volcanic tuff. The combinations of these several classes of material yield water about as commonly and under about the same conditions as littoral and alluvial deposits themselves.

CORALLINE LIMESTONE

Coralline limestone is generally dry where it occurs over extensive areas and in thickness. It is so porous and so thoroughly jointed and cavernous that water percolates through it with little hindrance. Only in coralline limestone that is interbedded with impervious beds of clay, marl, or other material is water confined so as to be available under hydrostatic pressure. Fortunately a great deal of the recent coralline limestone in the Philippines is interbedded with impervious material and, therefore, can often be made to yield water. Coral reefs have been found in buried littoral deposits, and in this position were saturated with water under pressure. More commonly coral reefs have been found in deposits of water-laid volcanic tuffs in relations which made the coral reef a natural reservoir for ground water. But the commonest condition under which water has been obtained from coralline limestone is that of interbedded

coralline limestone and clayey marl. The thick marl beds are impervious and confine the water in the intervening porous coral-reef members of the series.

Coralline limestone is most abundant in the Visayan Islands, especially in Cebu and Bohol. On both these islands it includes marl beds. Good wells have been obtained in this formation in only about 50 per cent of the trials made. The chance of encountering salt water is great if the well is drilled to a depth which carries it much below sea level. In drilling through coral, the hole should not advance far beyond the casing, even though the wells may stand up well, and especial watch should be maintained for impervious layers which may act as confining agents.

VOLCANIC BRECCIAS AND AGGLOMERATES

Volcanic breccias and agglomerates, made up of varyingly coarse and fine fragmental material embedded in tuff, are very common in the Philippines. These rocks have usually been deposited on the sea floor and, therefore, have been worked over and roughly stratified by water, but heterogeneous breccias and agglomerates of subaërial deposition are also known. These rocks are found in the immediate vicinities of old volcanoes and along lines of former volcanic activity. Much of the material is indurated and impervious, but an equal proportion, perhaps, is loose and porous.

In massive breccias or agglomerates there is only slight chance of obtaining artesian water, but where the fragmental material has been deposited on a sea floor, and is, therefore, somewhat bedded, artesian water may be obtained. Wells on the southeastern and eastern shores of Laguna de Bay have yielded good flows from this class of rock. There is a considerable area of bedded volcanic agglomerate around the base of Mount Isarog in Camarines which ought to yield water, and likewise in northern Camarines and in Sorsogon there are places at which it is suspected rocks of this nature are water-bearing. On the whole, however, volcanic breccias and agglomerates are rather uncertain territory for the artesian-well driller.

Mineralized water is often encountered in massive volcanic agglomerate. Hot springs and other evidences of solfataric action are associated with these rocks, so that in addition to the possibility of encountering no water there is the further chance that if water is encountered it may be too thoroughly mineralized to be potable.

BEDDED VOLCANIC TUFF

Bedded volcanic tuff is found extensively in southwestern Luzon and has proved to be particularly reliable as a source of artesian water. This tuff has not been indurated nor consolidated through folding processes; it is distinctly bedded and generally porous, but the successive beds are varyingly fine-grained, so that conditions for confining water under some pressure are very good. Many of the wells in the bedded tuff have yielded flows, and a great majority have yielded either pumping or flowing water. The bedded tuff formation is, perhaps, more uniformly water-bearing than any other of the Philippine rock series.

TERTIARY SEDIMENTARIES

The Tertiary (Miocene) sedimentaries consist of shales, sandstones, conglomerates, and limestones. The formation is encountered in various parts of Luzon; it makes up nearly the whole of the area of Samar; and it is important in Leyte, Cebu, Panay, and in parts of Mindanao. Coal and petroleum are found only in the Tertiary sedimentaries in the Philippines, and the distribution of these minerals may be used as a guide in this connection. The shales and sandstones are made up in large proportion of volcanic material. The series as a whole is indurated and close-grained; consequently it carries but little water. Moreover the fine-grained beds retain a great deal of their original salt content, and this contaminates any water which is obtained from them. Only a small number of wells have penetrated the sedimentary series, and only a small proportion of these have been successful. Where this series of beds constitutes the underlying formation, a serious effort should be made to obtain potable waters in the surface alluvium if it is available. Deep wells are to be undertaken only as a last resort.

It must be admitted that some artesian water has been obtained from the sedimentary rocks, but the flows are invariably small, and no eminently satisfactory wells have been drilled into the formation. The sandstones and the conglomerates yield water under favorable conditions, but even these rocks are too dense to be of great promise. The limestone members of the series are very cavernous and jointed, and water percolates through them readily. The lower limestone, which is very close to the base of the sedimentary series, is undoubtedly the most important possible source of artesian water in this formation.

At its outcrop this limestone is corroded and jointed until it is a very porous rock. The sedimentary series is usually found flanking the cordilleras and dipping away from them, so that very often this basal limestone is exposed in a region of heavy rainfall and lies at an angle which accelerates the percolation of water along it. If the limestone in this relation were penetrated by a well, it ought to yield water copiously. The difficulties are that the basal limestone is thin, discontinuous, and broken by faulting; that inasmuch as its porosity in surface exposures is due largely to solution, the limestone may not be porous below the permanent level of ground water; and finally, that its stratigraphic position is such that it is commonly too deeply buried, except in mountainous and consequently uninhabited regions, to be accessible by drilling. The conditions afford a chance, however, which should be tested when opportunity presents.

MASSIVE IGNEOUS ROCKS

Massive igneous rocks abound in all of the truly mountainous portions of the Philippine Islands. Igneous rocks, wherever present to the exclusion of other rocks, constitute the formation least favorable to the accumulation of potable artesian water. They are impermeable to water because of their dense nonporous texture and the absence of bedding planes. It is generally immaterial in this connection whether the igneous rock is of the deep-seated, holocrystalline type, such as the diorites, gabbros, peridotites, and occasional granites, or is one of the surface lava flows, such as the widely distributed andesites and less common basalts, rhyolites, and dacites, although infrequently solidified lava flows are so vesicular and porous as to be permeable to water. Very rarely do common igneous rocks yield water in quantity. No Philippine wells have encountered water in massive igneous rocks, although a dozen, perhaps, have been drilled into them. Minute quantities of water are contained along fractures and joints in igneous rocks, and often mineralized water is encountered in the occasional veins and shear zones; otherwise the rocks are almost invariably dry. Obviously, therefore, igneous rocks are to be avoided in choosing sites for artesian wells.

METAMORPHIC ROCKS

Metamorphic types of rocks are represented in the Philippines principally by schists, with subordinate gneisses and marbles. Because of their dense nature metamorphic rocks are not

common sources of artesian water. In the Philippines they are of limited distribution and consequently unimportant; as yet no wells have been drilled into them. Water might be obtained from buried marble, which is often cavernous, but schist and gneiss would probably be found to be dry.

Schists and gneisses, together with massive igneous rocks, are the basal formations in the Philippine rock series and will, therefore, be encountered ultimately in practically any locality in the Islands if the drilling proceeds to a sufficient depth. Since they are devoid of water, no attempt should be made to continue drilling once these formations are encountered.

PETROLEUM AND RESIDUAL BITUMENS IN LEYTE [1]

By WALLACE E. PRATT

(*From the Division of Mines, Bureau of Science, Manila, P. I.*)

ONE PLATE AND 2 TEXT FIGURES

CONTENTS

INTRODUCTION

The existence of petroleum in Leyte became known about the year 1890. In 1892, according to old Spanish records, an Englishman, named White, sought exclusive permission to exploit petroleum deposits in the Philippines and to refine the petroleum obtained therefrom. In his petition the applicant specified the northwestern part of Leyte and the Islands of Cebu, Bohol, Negros, and Panay as territory to be explored. Becker,[2] quoting various Spanish authorities, states that petroleum had been found in the jurisdiction of the town of San Isidro, Leyte. Sir Boverton Redwood [3] was informed by a Mr. Warren that petroleum was known to occur near the town of Villaba, Leyte. The people of the town of Villaba remember an attempt at exploitation about the year 1896 on a well-known seep near the barrio of Jinagnatan. Apparently this work, the men in charge of which are said to have been Belgians, was without result; certainly no wells of any depth were drilled. Adams [4] mentions

[1] Received for publication June 16, 1915.

[2] Report on the geology of the Philippine Islands, *21st Annual Rep. U. S. Geol. Surv.* (1901), pt. 3, 107, reprint.

[3] Petroleum and its Products. Charles Griffin & Co. Ltd., London. 2d ed. (1906), 56.

[4] *This Journal, Sec. A* (1909), 4, 355.

the reported occurrence of petroleum at Villaba, but had no opportunity to verify the reports.

Attention was recalled to the Villaba region by the reported discovery of asphalt there in 1913. The original discovery was made by a Filipino ranger in the forest service in mountainous country about 10 kilometers northeast of Villaba. The material found by the forest ranger is a brittle, solid bitumen, brownish black in color, schistose or irregular in fracture, and high in its content of paraffin. This discovery was followed immediately by a period of active prospecting and claim location. A number of other outcrops of material similar in character to the forest ranger's outcrop have been located, and other outcrops and seepages of hydrocarbons, ranging in character from petroleum itself, through viscous liquids and semisolids, to hard, coallike bitumens, are now known. Bitumen-impregnated limestone and sandstone have also been found. A majority of the later discoveries are nearer to the seacoast and in less mountainous country than the first find, a feature which has stimulated prospecting.

At the present time there are about 30 claims in the district. Approximately one half of these are individual claims, 8 hectares in area; the remainder are association claims, 64 hectares in area. A majority of the claim holders have pooled their interests and have incorporated under the name of The Leyte Asphalt and Mineral Oil Company, Limited.

The notes upon which the present paper is based were made during a visit of a week's duration in May, 1915.

SITUATION

Villaba is situated on the western coast of northern Leyte. The petroleum seep whose existence is noted by Becker and by Redwood lies near the seacoast about 4 kilometers north of Villaba; it is just inland from Burabod Point between the barrios of Jinagnatan and Campocpoc. The solid bitumens first discovered occur at the western base of the ridge surmounted by Mount Benao and to the south of that mountain in the valley of one of the streams at the head of Butason River. Other seepages of petroleum, which were evidently not known to the Spaniards, have recently been found at the head of the valley east of Villaba at a distance of about 4 kilometers from that town. Other outcrops of solid bitumens have been found around the western base of Mount Benao, and viscous bitumens seep from the banks of a creek which flows into Butason River farther west than the outcrop first discovered. A mixture of solid

bitumen and fragments of clay-tuff has been discovered in the edge of the town of Villaba itself. This deposit appears to be of considerable extent laterally. To the south of Villaba at a distance of about 3 kilometers there is a large outcrop of bitumen-impregnated limestone, and east of this occurrence there is another small outcrop of solid or semisolid bitumen. Finally, viscous black bitumen has been found just inland from the barrio of Tabubunga, 10 kilometers south of Villaba. Both petroleum and solid bitumen are reported from other places in northwestern Leyte, but these reports were not verified. Some of them appear upon examination to be unreliable, but in view of the geology of the region it will be surprising if other occurrences of petroleum and bitumens derived from petroleum are not discovered.

The principal known occurrences of petroleum and related bitumens, therefore, are distributed over an area 8 kilometers wide and 13 kilometers long. The peninsular portion of northwestern Leyte as far south as the barrio of Baliti is a geologic unit and should be included in the area which may contain petroleum, although surface indications of petroleum will probably not be encountered in the northern part of the peninsula, because there erosion has not removed the cover of rocks overlying the petroleum-bearing formation as it has farther south.

The vicinity of Villaba is shown on the accompanying map, fig. 2, together with all of the known bitumen outcrops and petroleum seepages. In fig. 1 northwestern Leyte is shown in outline. Both these maps are based on Coast and Geodetic Survey charts. The situations of the outcrops as shown on the detailed map were obtained by compass surveys.

PHYSIOGRAPHY

Northwestern Leyte is of only moderate relief—rarely do the elevations exceed 350 meters—but the valleys are deeply incised, and the slopes are usually steep. The topography reflects strongly the geologic structure—nearly flat-topped ridges and hills in the extreme north where the strata are level or only slightly inclined, and sharp points and knife-edged divides in the steeply dipping shales farther south. A resistant limestone near the top of the rock series withstands erosion, so that in places it becomes a base upon which remain little groups or rows of regular conical hills carved out of the softer overlying sandstone.

The rainfall is carried off by a number of small drainage systems, so that within the petroleum region there are no large streams. The headwaters of the river which reaches the sea

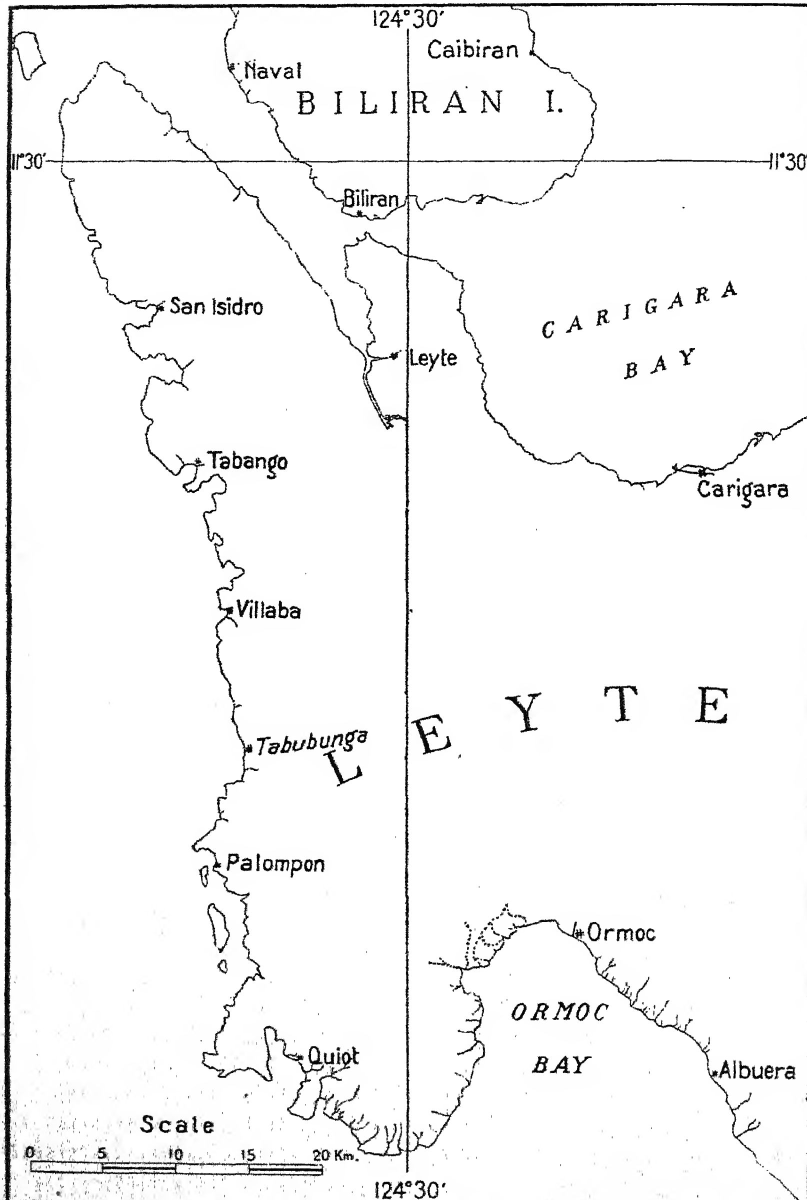


FIG. 1. Outline of northwestern Leyte.

at Ormoc are just south of Villaba, but the river does not attain a great volume within the confines of the petroleum-bearing territory. Likewise Butason River leaves the petroleum region behind before it attains any great size.

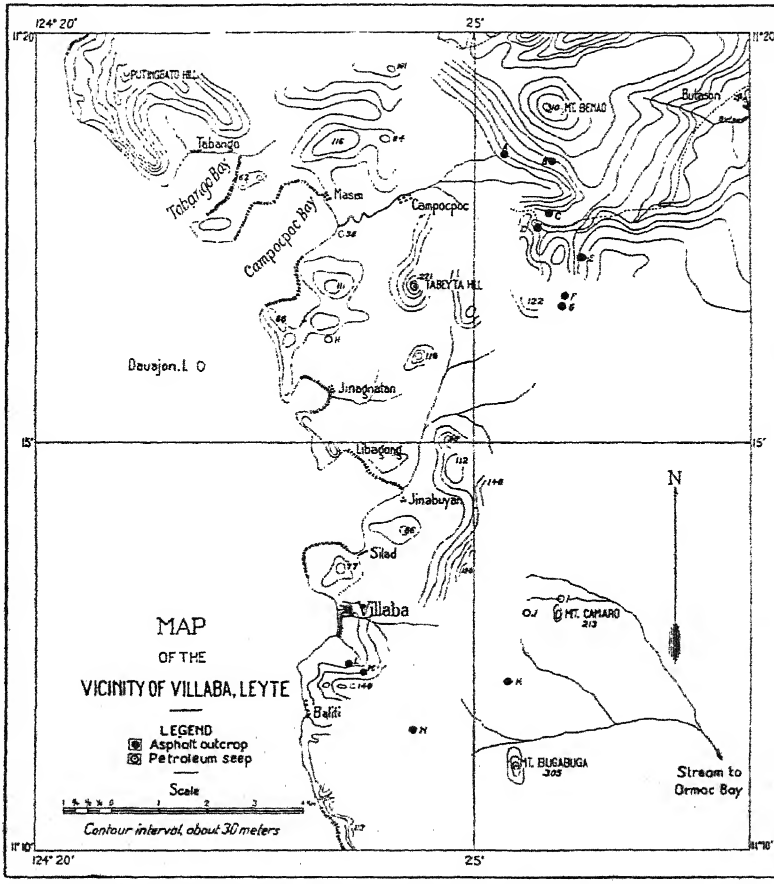


FIG. 2. Vicinity of Villaba, Leyte, showing the situations of outcrops of natural bitumens and seepages of petroleum.

The coast line of northwestern Leyte is generally regular and unbroken by indentations. The land mass rises abruptly from the seashore, and the streams are tidal for a comparatively short distance inland. In the vicinity of the petroleum-bearing area, however, the generally straight coast line is modified by a series

of sharp reëntrants, including San Isidro Bay, Arevalo Bay, and Campocpoc Bay. Evidently these conspicuous indentations have resulted from local folding.

GENERAL GEOLOGY

The geologic formation in northwestern Leyte is predominantly sedimentary and belongs to the late Tertiary and Post-Tertiary series of rocks. The several divisions can be correlated directly with the stratigraphic column as worked out by Pratt and Smith[5] in the Bondoc Peninsula petroleum region in Tayabas Province.

Thin-bedded shales and subordinate thin beds of sandstone of lower Miocene or Oligocene age make up the base of the series. These beds appear to have been laid down unconformably over a complex of igneous and metamorphic rocks of undetermined age. The name Vigo shale was applied to the thin-bedded shale and sandstone series because of typical occurrences along Vigo River in Tayabas. Petroleum is found in the Vigo both in Tayabas and Leyte.

Overlying the Vigo with some degree of unconformity is a massive or imperfectly bedded formation of clay-tuff and tuff-sandstone, which was designated as the Canguinsa sandstone in Tayabas. This formation yields petroleum and derived bitumens in Leyte, although it is barren or only faintly petroliferous in Tayabas.

Limestone and calcareous sandstone are encountered with apparent conformity, above the Canguinsa, in both Leyte and Tayabas. These rocks are known as the Malumbang series, and they mark the top of the stratigraphic column except for recently elevated coral reefs, littoral deposits, and modern alluvium. The Malumbang series contains no petroleum in Tayabas, but in Leyte it has been impregnated with petroleum in at least one place with the formation of bituminous limestone and bituminous sandstone as a result.

The total thickness of the sedimentary formations in Tayabas was estimated at from 1,700 to 1,800 meters, and the sections which can be measured in Leyte show corresponding thicknesses.

The presence of several small intrusions of andesite and andesite-agglomerate was recorded in the report on the Tayabas region. In the Leyte field intrusions of this class are much more prominent and numerous. One of the most conspicuous hills in the vicinity of Villaba, namely, Mount Tabeyta, consists of andesite and andesite-agglomerate, and a half-dozen smaller intru-

[5] *This Journal, Sec. A* (1913), 8, 301 et seq.

sions, distributed throughout the petroleum-bearing region, were observed.

The sedimentaries in northwestern Leyte are generally tilted so as to have a strike of north 60° west with dips of from 10° to 20° at right angles to this line in either direction; locally the strata have been thrown into sharper folds in which, however, the general west-northwest strike is maintained. At places along the coasts even the general strike is lost, and the attitude of the beds is widely different over short distances. The more intense folds are in the intruded areas and are probably accompanied by faulting.

STRATIGRAPHY

Table I shows the stratigraphy of the Tayabas petroleum region as worked out by Pratt and Smith.[6] As modified in the following discussion, the table serves admirably for the Leyte petroleum region, the correlation of the principal divisions being perfect.

ALLUVIAL AND LITTORAL DEPOSITS

Alluvium is of minor occurrence in northwestern Leyte and demands little attention. Sand and clay derived from the sedimentary rocks, with pebbles from the intrusives and coralline limestones, border the lower courses of the streams. Raised coral reefs are encountered along the coasts and indicate an elevation of the land mass continuing into recent time. Fragmental coral and other littoral débris have been elevated with the reefs, and the deposits have a roughly bedded structure in which the dividing planes are frequently inclined at considerable angles.

MALUMBANG SERIES

The Malumbang series has not been studied as closely in Leyte as it has in Tayabas; in the last-named region it was found to be nonuniform both in thickness and in character. An upper and lower limestone with an intervening sandstone were found at some places in Tayabas, but at other places the lower limestone appeared to be missing, and the sections rarely included all three divisions. In Leyte the series is similarly inconstant in character. It can hardly be described more definitely than as an irregular succession of calcareous beds, ranging from chalky limestone through calcareous sandstone to coralline limestone. The chalky beds are more prominent in Leyte than in

[6] Op. cit., 312.

TABLE I.—*Provisional scheme of stratigraphy. Bondoc Peninsula, Tayabas.*

Series.	Formation.	Subdivisions and character.	Thickness.	Characteristic fossils.	Geologic condition of deposition.
			Meters.		
Recent	Alluvium	Clay, sand, gravel, and travertine	0-10		Fluviatile.
Pleistocene and Recent	Coral reefs and littoral deposits.	Raised coral reefs, beaches, etc	0-15	*Trochus fenestratus*, *Cerithium nodulosum*, *Telescopium* sp., *Conus flavidus*.	Seashore deposits during slow elevation.
Unconformity					
Pliocene and upper or middle Miocene.	Malumbang series	Upper limestone. Coralline to sandy	20-50	*Pyrula gigas*, *Lucina bacauensis*, *Cerithium* sp., *Solecurtus grandis*, *Spondylus imperialis*, *Operculina costata*, *Bulla ampulla*, *Pecten senatorius*, *Lithothamnium ramosissimum*.	Shallow seas, clear at times.
		Cudiapi sandstone. Bedded, calcareous, yellow to brown.	50-100		
		Lower limestone, white to yellow, coralline in part.	0-20		
Middle or lower Miocene.	Canguinsa sandstone.	Blue to gray, massive, clayey sandstone with gray calcareous sandstone and minor beds of limestone locally. A single small outcrop of volcanic agglomerate in base, not of general occurrence.	50-160	Large lepidocyclinas, *Cycloclypeus communis*.	Nonuniform conditions; both deep or quiet and shallow seas indicated; local extrusion.
Unconformity. Mechanical discordance and possible erosion.					
		Sandstone and fine sandy conglomerate, in alternate beds.	(?)	*Mitra* sp., *Pyrula* sp	
		Bacau stage. Massive or imperfectly bedded, bluish black shale with minor sandy zones. The principal oil seeps are associated with the Bacau stage, and shallow wells have obtained fair showings of oil in it.	50-160	*Conus loroisii*, *Conus striatellus*, *Globigerina*, *Conus hochstetteri*, *Tapes rimosa*.	Local extrusion. Shallow seas, gradual sub-

Lower Miocene or Oligocene. (?)	Vigo shale	A single outcrop of volcanic agglomerate at this horizon, but not of general occurrence. Gray shale, black shale, yellow and brown sandy shale, and sandstone interbedded in thin layers. Traces of oil and gas. Possible oil horizon in unexposed base. A single small exposure of volcanic agglomerate; not of general occurrence.	[a] 1,400	*Globigerina*, *Polystomella*	sidence. Water deepened late in the period, but became very shallow at close.
Eocene		Concealed or lacking			
Unconformity					
(?)		Basal conglomerate over diorite			

[a] Base not exposed.

Tayabas. They form smooth white faces, which are numerous along the western coast. They are encountered both above and below the calcareous sandstone, while the coralline limestones are usually above the sandstone. The chalky limestone appears to contain very fine tuff in some exposures.

South of Villaba and east of Baliti the Malumbang series has been impregnated with bitumen. The bituminous limestone and bituminous sandstone so formed outcrop at the head of a cañon near the summit of the hills. It is probable that the cañon marks a fault, since Vigo shale is exposed in the wall opposite the bitumen-impregnated face. Here the Malumbang series is at least 50 meters thick and is clearly conformable over the Canguinsa, both formations dipping at low angles to the south. The lower beds are calcareous sandstone (lower limestone missing), while the upper part of the series is fragmental, coralline limestone. Elsewhere in Leyte, especially on the northern part of the peninsula, the Malumbang series is much thicker and may attain a maximum of 200 meters.

In distribution the Malumbang may be said to be confined to the tops of the hills along the coast in the southern part of the region, extending inland farther north until it is intact across the north end of the peninsula. It is especially heavy on the northeastern coast of the peninsula.

CANGUINSA CLAY-TUFF

The Canguinsa as it occurs in Tayabas is a light gray, light brown, or light blue, massive clay-tuff, or clayey tuff-sandstone, both of which, although soft, are dense and tough as a result of their close, fine-grained texture. The rock is imperfectly bedded at places; elsewhere it is massive. It is usually slightly calcareous and contains numerous small fossils (Table I). It breaks with a subconchoidal fracture and weathers into fragments with concave faces, which are smooth and greasy to the touch and emit a faint odor of bitumen. At places toward its base the Canguinsa becomes fissile and takes on something of the character of the Vigo shale.

This description applies perfectly to the Canguinsa in Leyte, where it is in every respect similar to the Tayabas occurrences. A fact which escaped mention in the report on the Tayabas field, however, is that the Canguinsa contains a large proportion of volcanic tuff of varying fineness. In places it is a clay-tuff; at other places, a tuff-sandstone. The individual grains of tuff are sharp fragments of glass, calcic feldspar, and subordinate quartz.

The commonest fossil in the Canguinsa in Leyte is a species of *Globigerina*, a low form of animal life which builds a very small, spherical shell of calcium carbonate. These fossils were noted in the upper part of the Vigo shale in Tayabas, and the study of that field brought forth the suggestion that the petroleum, which undoubtedly comes from the Vigo, might have originated through the decomposition of the organic matter which the shells once contained. The Canguinsa in Leyte appears to contain even more examples of *Globigerina* than the Vigo; possibly 5 per cent of the area on an average surface of a fragment of Canguinsa clay-tuff from Leyte is covered by these small spheres.

No petroleum was detected in the Canguinsa in Tayabas, but in Leyte a majority of the outcrops of bituminous residues from petroleum occur in the Canguinsa, and at one place petroleum itself seeps from a tuff-sandstone phase of the Canguinsa.

The Canguinsa is the surface rock over the larger part of the Leyte petroleum field. It outcrops in the lower parts of the hills which are capped by the Malumbang series and is intact above the Vigo shale, except to the east and south of Jinabuyan and Villaba. The ridge which culminates in Mount Benao consists principally of Canguinsa rocks—clay-tuffs and clayey, tuff-sandstones. The western face of Mount Benao affords the best section of the Canguinsa observed in Leyte. In this region its thickness is at least 300 meters, a figure which is comparable with the estimated thickness of the same division of the Tayabas sedimentary column.

VIGO SHALE

The Vigo shale consists of alternating, thin, perfect beds of shale, sandy shale, and sandstone. The strata are differently colored—dark gray, brown, and yellow—and outcrops often present a variegated appearance. Toward the top of the formation, dark-colored fine-grained shale, in thicker and less perfectly defined beds, is predominant. This upper shale was referred to as the Bacau stage of the Vigo in the report on the Tayabas field, having been differentiated there because it appears to be more petroliferous than the underlying beds. The Vigo is like the Canguinsa in that its beds, both shale and sandstone, appear to contain considerable tuffaceous material. The sandstone beds, for instance, are made up of sharp or slightly rounded fragments of feldspar, ferromagnesian minerals, glass, and quartz. Unlike the Canguinsa, on the other hand, the Vigo rocks are somewhat indurated and usually fissile, so that they split into thin laminæ on disintegration. The fine-grained shale at the top of

the Vigo, however, is not fissile and except for its darker color resembles the overlying Canguinsa. It weathers into ellipsoids, the forms of which stand out along the exposed edges of the beds, with their major axes in the plane of the stratum.

The Vigo shale is probably about 1,000 meters in maximum thickness in Leyte, although complete sections were not observed. Undoubtedly the thickness varies, because it is known to overlap, unconformably, the formation upon which it rests. The most extensive exposures lie to the east and south of Villaba, while smaller outcrops are encountered at various places in the surrounding country.

Petroleum seeps from the Vigo at half a dozen places in Tayabas. Apparently it always comes from the upper part of the formation. In Leyte two petroleum seeps were found in the Vigo shale, and a very heavy, black, oil-liquid bitumen was encountered in sandstone, closely above the basal complex upon which the Vigo lies. The solid bitumens which occur in the overlying Canguinsa were nowhere observed in the Vigo.

INTRUSIVE ROCKS

The intrusive rocks in Leyte are principally andesites and andesite-breccias. Similar intrusions were observed in Tayabas, and the rocks of which they consist were described in the report on that region. In Leyte the andesites are usually porphyritic with phenocrysts of ferromagnesian minerals and occasional calcic feldspars in a light-colored groundmass. Other specimens are dark-colored, fine-grained, homogeneous rocks.

A single outcrop of an igneous rock, which appears to be diorite, is encountered at petroleum seepage I. This rock is somewhat decomposed, is holocrystalline in texture, and consists essentially of calcic feldspars and hornblende or pyroxene. The outcrop is at a low horizon in the Vigo shale and may represent a part of the basal igneous complex instead of an intrusion.

The intrusive nature of the andesites is indicated by their relation to the strata in the surrounding sedimentaries; by the presence in at least two places of adjacent springs of warm mineralized water which emits an odor of hydrogen sulphide; by rare fragments of quartz, chert, and partly baked shale in the rocks surrounding the intrusion; and in the case of the Mount Tabeyta intrusion, by remnants of a calcite- and quartz-cemented shale-breccia surmounting the andesite.

The intrusions penetrate the Vigo shale and the Canguinsa clay-tuff. Mount Tabeyta and the isolated conical hill at the
River are the largest and most conspicuous

of the intrusions, but there are numerous smaller outcrops east and south of Villaba.

It is believed that the intrusions have been instrumental in driving the petroleum upward through the surrounding rocks. One of the observed petroleum seeps is on the contact of an apparently intrusive holocrystalline rock in the Vigo shale. All the petroleum and solid bitumen occurrences are near intrusions, and viscous or semiliquid bitumen is found in concretions and brecciated concretionlike bodies, the origin of which may reasonably be attributed to solutions given off by buried intrusions.

More detailed descriptions of each of the formations represented in Leyte will be found in the report cited on the Tayabas field, and other observations are recorded in the descriptions of the occurrences of the hydrocarbons in the present paper. The age of the various divisions was determined by Smith from his study of the included fossil remains as follows: Alluvium and littoral deposits, Recent; raised coral reefs, Recent to Pleistocene; Malumbang series, Pliocene and upper or middle Miocene; Canguinsa clay-tuff, middle or lower Miocene; Vigo shale, lower Miocene or Oligocene. The intrusive rocks are younger than the Canguinsa and are evidently younger than the Malumbang series if they are responsible for the dispersion of the bituminous matter which is observed to impregnate part of the Malumbang series south of Villaba.

STRUCTURE

The structure of the Leyte petroleum region has been complicated by the intrusions which have penetrated the bedded rocks. The predominant strike is west-northwest. The dips are usually not greater than 30°, but locally they exceed this angle, especially in the Vigo shale, which commonly shows a greater inclination than the overlying beds. There are lines of local folding with dips in opposite directions on either side. Most of these folds trend west-northwest in the direction of the general strike, but this is not universally true. Along the coasts there is a tendency at several places for the strata to dip seaward, the strike corresponding to the general direction of the coast line.

The bitumens and the intrusive rocks alike appear in or near arches or domes in the structure. Nowhere are they found in clearly defined synclines.

There is an anticline with west-northwest axis near the head of Butason River. Outcrop D lies on the southern limb, and outcrops A and B lie on the northern limb of this fold. At outcrops E, F, and G, however, the dip is uniformly north-northeast, showing that the fold does not persist far eastward. Between

seepages I and J, again, there is a west-northwest-trending anticline in the Vigo shale, with Mount Camaro lying on its crest. The seepage at I on the northern limb of this fold is marked by igneous rocks which may be either intrusive or a part of the basal complex which underlies the Vigo shale. The outcrop N is on a fault trending west-northwest, along which there is also a small intrusion and from which the strata dip away on either side.

The southern part of the petroleum region, therefore, appears to contain a number of small folds, the majority of which have not yet been delineated. There are probably also more faults than have been detected. The intrusions, to judge from their distribution, are related to the folds in origin. In the northern part of the peninsula the folding processes have been less intense, and low broad folds would be expected in this territory.

Both in Tayabas and in Leyte there is a discordance between the Vigo shale and the overlying Canguinsa. This discordance is evidenced by an abrupt flattening in the angle of dip on passing from the Vigo to the Canguinsa in sharply folded areas. The dip is constantly in the same direction, but is less pronounced in the upper rocks than it is in the Vigo. Where the folding processes have not been intense, and the dips are consequently not steep, there is apparent conformity between the two formations. The possibility of an unconformity between the Vigo and the Canguinsa was discussed at length in the report on the Tayabas region. The question is important if, as is suggested, the Vigo shale is the petroleum-bearing formation. No conclusive evidence of an erosional unconformity was discovered, and it is, therefore, suggested that the observed difference in the angles of dip in the two formations might be explained as a mechanical discordance. It is conceived that the perfectly and closely laminated character of the Vigo shale would tend to cause it to respond more readily and more completely to processes of folding than would the heavily bedded or massive Canguinsa. The result might be a crumpling or wrinkling of the Vigo shale, which would be less plainly manifested in the more competent arch of the overlying Canguinsa.

Whether the unconformity between the Vigo and the Canguinsa is erosional or only a mechanical discordance is not conclusively determined. If it is erosional, there may, of course, be structures in the Vigo shale where it is covered by the upper rocks which are not reflected on the surface. Likewise there would be an overlap of the upper rocks on the upturned edges of the Vigo. If the discordance is only mechanical, there may

still be a slight overlap on the limbs of steep folds, but the structure as determined by the attitude of the upper beds must be practically the same in the underlying, petroleum-bearing Vigo shale.

OCCURRENCE OF THE PETROLEUM AND RESIDUAL BITUMENS

In Leyte petroleum is encountered at two places: namely, seeping from the upturned edges of the Vigo shale and oozing from the base of a hill which consists of a clayey tuff-sandstone belonging to the Canguinsa. Residual bitumens occur in the Canguinsa and in the Malumbang series; one questionable outcrop of solid bitumen was observed in loose débris which appears to overlie the Vigo shale, and a heavy, black oil or viscous bitumen was found in sandstone near the base of the Vigo.

The bitumens in the Canguinsa are encountered in five types of deposits: (1) solid bitumens in lenses or pockets which tend to follow bedding planes, but which also cross the bedding irregularly along fractures and cavities; (2) solid bitumens in regular fissures which penetrate the clay-tuff independently of bedding planes; (3) in nonuniform mixtures of bitumen-impregnated, clay-tuff fragments and subordinate solid bitumen; (4) viscous or semiliquid bitumen-cementing breccias of flintlike limestone, small domes of which protrude from the surface of the clay-tuff formation; and (5) viscous or semisolid bitumen filling the centers of hollow, cylindrical concretions which occur in the clay tuff, with their longer axes nearly vertical and at right angles to bedding planes. The bitumen in the Malumbang series has impregnated porous limestone and sandstone, forming what is known commercially as rock asphalt. The various occurrences both of petroleum and of residual bitumen, which are indicated on the map (fig. 2) by letter, will be described separately. Chemical data on the petroleum and the bitumens will be found in the discussion on the character of the bitumens.

Outcrops A and B are jet black, lustrous bitumens with conchoidal fracture, which have been mistaken by the Filipinos who live in the vicinity for coal. The bitumen has a specific gravity of 1.05, a black streak, and a hardness, at ordinary temperature, of not more than 2. It melts readily, intumesces, and flows imperfectly. Upon distillation it yields a delicate coke. The outcrops have been on fire at various times, either through spontaneous combustion or, more probably, through kindling from the grass fires which sweep the region nearly every year, and the clay surrounding them is baked to a red sinter at places. Both deposits are found in Canguinsa clay-tuff at the base of

Mount Benao, with at least 250 meters' thickness of this formation stratigraphically above them.

Outcrop A is in a creek which flows into Campocpoc River. Several exposures have been found at the surface, but attempts to follow them with excavations have failed. Evidently only loose débris or surface float from the true deposit, whatever its nature may be, has as yet been discovered. In all, perhaps one ton of bitumen has been recovered.

At B a small vertical fissure filled with solid bitumen has been exposed by a shaft about 3 meters deep. There are other outcrops of similar bitumen near by, but only the one has been opened enough to reveal its form. This fissure has sharp, regular walls and widens downward from 30 centimeters at the surface to 60 centimeters at the bottom of the opening. The bitumen is closely jointed at right angles to the walls, so that it is removed in roughly columnar fragments. A small lens of the clay wall was observed in the fissure surrounded by bitumen, and small seams of bitumen extend out from the fissure along joint planes in the clay, although there is no general impregnation of the surrounding walls. The fissure trends a little north of east across the beds of the Canguinsa, which strike west-northwest and dip about 20° north-northeast.

Outcrop C is identical in character with outcrop A. Nothing in place has been discovered, but pieces of black, shiny bitumen are scattered over the surface on the side of a hill of Canguinsa clay-tuff. Probably both at A and C fissures similar to the one at B will be found.

At D there are several outcrops of viscous, black bitumen along the bed of a small stream. The material varies from a semi-liquid, through a sticky, viscous stage, to a rubbery semisolid. The largest outcrop is a dome of bitumen-cemented breccia about 1 meter in diameter, which protrudes nearly a meter from the surface of the Canguinsa clay-tuff in the creek floor. The bitumen binds together the rock fragments in the breccia and also occupies pores and vesicles in the fragments themselves. There are at least two other outcrops of the same character. A shallow excavation around the base of the larger dome shows that it continues downward through the clay-tuff beds. Apparently these breccia domes or chimneys penetrate the strata, although there is no evidence of disturbance in the clay-tuff surrounding them.

The outcrops are in the basal part of the Canguinsa, very closely above the Vigo shale. The dip in the surrounding rocks is about 30° to the south-southwest. A few hundred meters to

the north the dip changes in direction to the north-northeast and continues unchanged to the region of Mount Benao. Thus an anticline is indicated, the axis of which trends west-northwest and lies close to the north of D outcrop. The southern limb of this fold is not persistent, north-northeast dips being again encountered at a distance of 1 kilometer south of the axis.

The fragments in the breccia are compact, flintlike rocks, which can best be described, perhaps, by likening them to portions of the clay-tuff hardened through impregnation by mineralizing solutions. That the hard rock may, indeed, have originated by some such process is suggested by the presence in the same neighborhood of peculiar concretions of the same flint-like material in the clay-tuff. These concretions, which have been spoken of as tubelike, are hollow, thick-walled, nearly vertical cylinders, piercing the strata. The hollow centers of these concretions, also, are filled with bitumen, and vesicles in the concretion walls contain bitumen. Thin sections of specimens of the breccia and of the concretions show small annular casts which might be taken to represent *Globigerina*. *Globigerina* is found both in the Canguinsa and in the Vigo, so that the breccia might be portions of either of these formations so far as this evidence is concerned. Photographs of both the breccia domes and the concretions appear in Plate I.

The following analyses show in part the composition of a fragment from the breccia and of a piece of clay-tuff from the surrounding beds:

TABLE II.—*Analyses of breccia and of clay-tuff from Canguinsa clay-tuff: outcrop D, Butason River, Villaba, Leyte.*[a]

Constituent.	Clay-tuff.	Breccia.
Silica (SiO_2)	37.98	5.73
Alumina (Al_2O_3)	8.93	5.98
Ferric oxide (Fe_2O_3)	6.24	0.38
Ferrous oxide (FeO)	3.77	1.96
Calcium oxide (CaO)	17.56	28.80
Magnesium oxide (MgO)	3.80	13.80
Loss on ignition	21.56	43.22
Total	99.84	99.87

[a] Analyses by T. Dar Juan, chemist, Bureau of Science.

If the breccia rocks have been formed by the action of solutions on clay-tuff, the change has consisted principally in the addition of magnesium and calcium carbonates (especially magnesium carbonate) and the subtraction of silica. These results could be accomplished apparently by an alkaline solution, but it is not clear how the decrease in ferric iron could have been

brought about by the same solution. The question of the origin of the breccias will require further study. Several mineral springs occur in northwestern Leyte, and analyses by the Bureau of Science of the waters from one of them, situated at Villahermosa, north of San Isidro, show an extremely high carbonic acid content with fair quantities of calcium, sodium, and magnesium.

The analysis of the clay-tuff at first sight does not bear out the conclusion that tuff is an important part of the rock. The silica-alumina ratio, however, is approximately the same as that of tuff in Cebu, which can be correlated stratigraphically with the Leyte clay-tuff, and the calcium, magnesium, and iron salts can be accounted for as additions from the sea water into which the tuff fell.

The total quantity of bitumen in sight at D is insignificant, but exploration might reveal a greater quantity and at the same time yield valuable information as to the origin of the bitumen deposits.

Outcrop D is in the general vicinity of the Mount Tabeyta intrusion, although at some distance (3 kilometers) from the peak itself. A clay-shale-breccia cemented by calcite and quartz, as has already been noted, was found on the summit of Mount Tabeyta. The suggestion may be put forward that the breccias and concretions at outcrop D are related to buried intrusions in their origin. The solutions which have impregnated the breccias and concretions might conceivably have been given off by an intrusion, but the manner in which the brecciation was accomplished without disturbing the surrounding clay-tuff beds is not clear. Although the Canguinsa clay-tuff is slightly petroliferous, there is certainly not enough bitumen in it to account for the concentration represented by the bitumen-cement in the breccias. Bitumen must, therefore, have been introduced into these broken rocks and solution channels, and the most reasonable assumption is that it ascended from a source in the underlying rocks—that is, from the Vigo shale.

Outcrops E, F, and G are pockets and irregular deposits of a solid, brownish black bitumen in Canguinsa clay-tuff. There are several other unmarked outcrops in the same region. The pockets follow bedding planes in the clay-tuff in a rough way, but also cross the beds irregularly and fill vertical openings in the formation. Several outcrops have been explored by short tunnels and by shafts, and a total quantity of perhaps 100 tons of bitumen has been recovered. The thickness of the deposits is rarely more than 1 meter, and some of them have

failed laterally within distances of 10 meters. The openings are all filled with either débris or water, so that they afford little opportunity for the detailed examination of the deposits.

The bitumen has a schistose appearance and an irregular schistose fracture. Its specific gravity varies from 1.02 to 1.05, depending, perhaps, on the degree of freedom from inorganic impurities. The streak is brownish, somewhat lighter than the color of the bitumen itself. The deposits are at a higher horizon in the Canguinsa clay-tuff than the outcrops at D, and the attitude of the beds is again that at outcrops A and B: namely, strike, west-northwest; dip, 20° north-northeast.

At the point marked H on the map there is a petroleum seep in the Canguinsa tuff-sandstone. Except for the Mount Tabeyta intrusives only Canguinsa rocks are exposed in the neighborhood. The petroleum escapes in very small quantity from cracks and joints, but does not impregnate the rock itself. The strata appear to be about horizontal, but bedding planes are not clearly defined. The seepage is at the base of a hill barely above sea level. On the beach near by is a spring of mineralized water, which emits an odor of hydrogen sulphide. The attempt made during the Spanish régime to exploit the Leyte petroleum deposits centered at the seepage H. There is no evidence now that anything whatever was accomplished in these attempts.

The petroleum seep at I is in a stream bed which is deeply cut into the Vigo shale. The oil drips from the wall of the creek along the contact between the Vigo shale and diorite. The igneous rock appears to be a lens between beds of steeply dipping shale and from its position might be an intrusion. No evidence of disturbance or metamorphism is to be observed in the shale, however, and the igneous rock may be part of the base upon which the Vigo shale lies instead of an intrusion. On both sides of the diorite exposure, the width of which is a few meters only, the shale is very regular and dips to the north-northeast at an angle of 50°. To the north the Vigo shale is exposed continuously for a distance of at least 800 meters, maintaining always the same attitude. About 300 meters south of the seep the dip changes in direction to the south-southwest and decreases to about 30°, the strike remaining constant. Thus an anticline is indicated in the Vigo shale. Mount Camaro, in which the strata appear to be nearly horizontal, marks the crest of this fold, and the petroleum seeps I and J lie on the opposite limbs very near the axis.

The petroleum at the point marked J comes directly from the

upturned edges of the Vigo shale. A pit about 2 meters deep was dug at J, and enough petroleum was encountered to make possible the collection of a 1-liter sample. Gas escaped from the floor of the pit with a slight rushing sound and moved small pieces of débris around which it flowed. The shale in the pit walls is dark in color and is impregnated with petroleum, although the flow of petroleum came from bedding planes and joints. Dark gray sandstone occurs in the shale, but while it has a strong petroliferous odor, it is not impregnated with petroleum. About 500 meters to the east of the seepage at J the Canguinsa rocks are encountered overlying the Vigo, but directly south of the seep the Vigo is exposed over a greater distance. The seepages at both I and J, therefore, come from beds which are well below the top of the Vigo shale. If the igneous rock at I is not intrusive, then the one seepage must be in the very base of the Vigo.

The petroleum at J is very fluid and has an odor of light oils. It is olive-green by reflected light and reddish brown by transmitted light. The results of fractional distillation appear in Table V under the discussion of the character of the petroleum and bitumens. Apparently the petroleum at H and I is of the same character as that at J.

At the point marked K there is a small outcrop of semisolid, black bitumen filling a pocket in loose limestone and clay. There are no good outcrops in the immediate vicinity, but it is probable that Vigo shale is the underlying rock. The outcrop is too small to afford any idea of the character of the bitumen or of the manner of its occurrence.

At L and M, near the town of Villaba, there is an apparently extensive deposit of solid bitumen mixed with fragments of Canguinsa clay-tuff. This material is encountered just beneath the surface and has been opened by shallow pits at two places about 300 meters apart. About 100 tons of the mixture have been mined from these openings, one of which reached a depth of 5 meters continuously in the bituminous material. The bitumen in this deposit is like that in the region of the E, F, and G outcrops in character, but within a few meters of the openings there are also domes or chimneys of brecciated, hardened clay-tuff cemented with viscous bitumen like the material in the outcrops at D. Outcrops L and M appear to be in the upper part of the Canguinsa clay-tuff, which in this vicinity dips at low angles to the south.

At the point marked N on the map in fig. 2 is the deposit of bituminous limestone already mentioned. At this place porous

limestone and porous sandstone belonging to the Malumbang series have been saturated with a viscous, black bitumen. The Malumbang series is at least 50 meters thick here, and the beds dip gently to the south. The outcrop is a cliff 12 to 20 meters high, forming one wall of a cañon. The impregnation extends over a distance of at least 50 meters along the cañon floor. No exploration has been performed, and there is no evidence as to how far at right angles to the exposed face the impregnation may continue. The lower bituminous beds are sandstone made up of fine fragments of limestone, feldspar, glass, and quartz. The upper beds consist of a granular limestone which does not disintegrate upon the removal of the bituminous impregnation. Blocks of the bituminous material of many tons' weight have been broken off and carried down the cañon.

Across the cañon from the bituminous beds in the Malumbang series, exposures of Vigo shale were observed dipping at a high angle in a direction opposite to that in which the Malumbang dips. The relations suggest the presence of a fault in the vicinity, on one side of which the Vigo shale has been thrust up until it is in contact with the Malumbang on the opposite side.

On going down the cañon westward, Canguinsa clay-tuff is encountered beneath the Malumbang series, and in the floor of the cañon near the base of the Canguinsa one of the bitumen-filled cylindrical concretions, like those noted at outcrop D, was observed. At a distance of about 1 kilometer from the deposit, and at an elevation about 100 meters lower, Vigo shale appears beneath the Canguinsa. The Vigo in this position dips to the south at an angle of about 30° and is thus in conformity with the overlying rocks. A small outcrop of andesite occurs a few meters farther down the cañon toward Baliti; it is evidently an intrusion in the Vigo shale.

Near the barrio of Tabubunga, 10 kilometers south of Villaba and outside the area included in fig. 2, I saw a small quantity of a viscous, black oil seeping from joints in a thin bed of sandstone near the base of the Vigo shale. This seepage is somewhat more than 1 kilometer inland from Tabubunga along Tabubunga River, at an elevation of about 30 meters. In going to the seepage from Tabubunga, I crossed successively the Malumbang series, the Canguinsa clay-shale, and practically all of the Vigo shale almost to the contact of the latter with the basal complex upon which the sedimentaries lie. The dip is constantly seaward (west) at an angle of about 30° throughout each of the formations. Thus the sedimentary formations are much thinner at Tabubunga than they are at Villaba. The thickness of the Vigo

shale especially has diminished in the section at Tabubunga, a condition which is due probably to the varying overlap of its beds on the basal rocks.

CHARACTER OF THE PETROLEUM AND RESIDUAL BITUMENS

Natural bitumens are generally conceded to have their origin in petroleum and to consist of various hydrocarbon residuals, left upon the evaporation or dissipation of the more volatile constituents of petroleum. Definite mineral names have been applied to a number of natural bitumens of different character, and this mineral classification is assumed to be complete. But in attempting to classify the various bitumens in Leyte as one or another of the recognized bitumen minerals, I find that the descriptions of none of the several types apply exactly. If the facts that petroleums vary widely in character and that the residuums from each petroleum form a continuous series from petroleum at one end to a metamorphic product similar to coal at the other end are considered, the difficulty of placing all the possible residual bitumens in a half-dozen classes will be apparent. Yet it is obviously not desirable to consider each natural bitumen as a distinct mineral species and to give it a separate name. Consequently I have applied only the broad term natural bitumen to the petroleum residuals in Leyte.

The following table contains data as to the physical properties of the three principal types of natural bitumens found in Leyte: namely, (1) the material from outcrops A and B; (2) material from outcrop D; and (3) material from outcrops E, F, and G. The bitumen in the mixture at L and M resembles that from E, F, and G, while the bituminous cement in the limestone and at N is similar to the material in outcrop D.

TABLE III.—*Physical properties of natural bitumens from Villaba, Leyte.*

Property.	Outcrop.		
	A and B.	D.	E, F, and G.
Specific gravity	1.05	1.016	0.98–1.02.
Hardness	2.00		1.5.
Color	Jet black	Black	Brownish black.
Streak	Black		Light brown.
Luster	Brilliant		Dull.
Structure	Columnar	Viscous	Schistose.
Fracture	Conchoidal		Irregular schistose.
Flows	Intumesces, softens, and flows imperfectly at 150° C.	At 35° C.	At 75° C.

The Leyte natural bitumens are derived from a paraffin-base petroleum. This fact at once distinguishes them from asphalt, as most commonly defined, which is derived either naturally or artificially from petroleum with an asphaltic base. The natural bitumen from outcrops E, F, and G was classified at the time of its discovery as gilsonite (or uintahite, another name for the same mineral). But gilsonite is black and lustrous and breaks with a perfect conchoidal fracture. The material from this group of outcrops is dull brownish black and breaks with a schistose fracture. Its specific gravity and its hardness are both less than the corresponding figures for gilsonite. Moreover, gilsonite, according to Richardson,[7] who has devoted a great deal of study to this subject, is derived from a nonparaffin oil and is not soluble in paraffin residues. All the Leyte bitumens are paraffin-bearing and are, therefore, not gilsonite according to Richardson. The bitumen from outcrop B is more nearly like gilsonite in physical appearance, being brilliant black in color and conchoidal in fracture. Its streak, however, is black, while the streak of gilsonite is reddish brown, and it contains a large proportion of paraffin.

Grahamite, another natural bitumen, has something of the physical appearance of the bitumen from outcrops E, F, and G; Richardson states that it may be derived from paraffin petroleums. But grahamite is heavier than any of the Leyte bitumens and has a higher proportion of fixed carbon.

Ozocerite is defined as a native paraffin, the physical appearance of which varies. Its color may be the same as that of some of the Leyte bitumens, its specific gravity is somewhat less, and it probably contains a higher average proportion of paraffin.

The petroleum from Leyte is a light, fluid oil, olive-green by reflected light and reddish brown by transmitted light. Its character is shown by the fractionations recorded in the following tables. Table IV contains the analysis of a sample which was secured by Mr. William Anderson, of Tacloban, Leyte, from the seepage at I and had probably deteriorated by exposure.

TABLE IV.—*Distillation products of petroleum from seepage I, Villaba, Leyte.*[a]

Constituent.	Percentage by weight.
Gasoline (110° to 170° C.)	0.88
Kerosene (170° to 270° C.)	17.51
Heavy oils (270° to 315° C.)	19.91
Residue, pitch (above 315° C.)	61.70

[a] Analysis by A. S. Arguelles, chemist, Bureau of Science.

[7] *Journ. Am. Chem. Soc.* (1910), 2, 1032.

A sample which I collected from a shallow pit at seepage J, about fifteen hours after the pit was completed, yielded the following results upon distillation:

TABLE V.—*Distillation products from seepage J, Villaba, Leyte.*[a]

Constituent.	Percentage by weight.
Gasoline (0° to 150° C.)	5.4
Kerosene (150° to 300° C.)	33.7
Heavy oils (300° to 400° C.)	55.3
Residue, pitch (above 400° C.)	5.6

[a] Analysis by A. H. Wells, chemist, Bureau of Science.

This petroleum contains 8.14 per cent of paraffin. The specific gravity of the crude oil is 0.8597. Unfortunately the sample was too small to permit of specific gravity determinations on the individual fractions.

For purposes of comparison the following analyses of petroleums from Tayabas and from Cebu are quoted from the report on the Tayabas field.[8] Sample 1 was taken from a shallow well at Bahay, Tayabas, twenty-four hours after the well had been pumped dry. Sample 2 was taken from a well drilled at Toledo, Cebu, in 1896.

TABLE VI.—*Products of distillation of petroleum from Tayabas and Cebu.*

Constituent.	Sample 1.[a]		Sample 2.[b]	
	Specific gravity at 29° C.	Volume.	Specific gravity at 15° C.	Volume.
		Per. ct.		*Per. ct.*
Crude	0.8323		0.885	
Gasoline (below 150° C.)	0.7692	30.4	0.762	6.2
Kerosene (150 to 300° C.)	0.8333	50.9	0.832	42.32
Heavy oils (300° to 400° C.)[c]	0.9061	15.1	0.901	38.3
Residue (above 400° C.)[d]		3.6		13.17

[a] Analysis by E. R. Dovey, chemist, Bureau of Science. A determination on a separate sample of Tayabas petroleum yielded 8.1 per cent of paraffin.
[b] Analysis by H. C. Brill, chemist, Bureau of Science.
[c] Temperatures 300° to 375° C. for sample 2, heavy oils.
[d] Temperature above 375° C. for sample 2, residue.

It will be seen from the foregoing analyses that the Leyte petroleum is intermediate between the petroleum from Cebu

[8] *This Journal, Sec. A* (1913), **8**, 358.

and Tayabas in specific gravity and that all three petroleums contain high percentages of burning oils; all three oils, likewise, are high in paraffin.

Determinations by Mr. Arguelles show that the lustrous black, solid material from the outcrop at B contains 94.53 per cent of bitumen soluble in carbon disulphide, 3.89 per cent of paraffin scale, and 26.62 per cent of fixed carbon. The specific gravity of the sample tested was 1.068. The material cokes upon distillation.

Determinations by Mr. Arguelles on a sample of the sticky bitumen from the outcrop at D showed: Specific gravity, 1.016; total bitumen, 81.84 per cent; paraffin scale, 0.30 per cent; fixed carbon, 6.59 per cent. The penetration (test with No. 2 cambric needle for five seconds with 100 grams' weight) is 1.3 millimeters at 30° C. and 2.6 millimeters at 50° C. The softening point of this material is 35° C.

Determinations by Mr. Arguelles on the brownish black, solid bitumen from outcrops E, F, and G showed: Specific gravity, 1.026; penetration at 25° C., 0.6 millimeter; loss at 163° C. for five hours, 3.28 per cent; total bitumen, 93.79 per cent; organic insoluble constituents, 1.00 per cent; mineral matter, 5.21 per cent; paraffin, 11.05 per cent; fixed carbon, 7.68 per cent. The following table contains analyses of different samples of material from outcrops at E, F, and G. Sample 1 represents pure bitumen; sample 2, bitumen of poorer quality.

TABLE VII.—*Analyses of bitumens from outcrops E, F, and G, Villaba, Leyte.*[a]

Constituent.	Sample 1.	Sample 2.
	Per cent.	*Per cent.*
Moisture and loss at 100° C	0.56	2.80
Petrolene	63.45	26.26
Asphaltene	28.59	22.53
Organic nonbitumen	4.68	11.64
Mineral matter	2.38	36.78
Total	100.16	100.01

[a] Analyses by A. H. Wells, chemist, Bureau of Science.

In the mixture of bitumen and clay-tuff from outcrops L and M Mr. Arguelles found 25.12 per cent of total bitumen, 21.6 per cent of which is paraffin scale. Mr. Wells distilled from another sample of the mixture from these outcrops 17.46 per cent (material as received) of heavy oil, which he fractionated as follows:

TABLE VIII.—*Distillation products from heavy oil obtained from bituminous mixture at outcrops L and M, Villaba, Leyte.*

Constituent.	Per cent.
Gasoline (below 150° C.)	10.0
Kerosene (150° to 300° C.)	36.0
Heavy oils (300° to 400° C.)	52.0
Pitch residue (over 400° C.)	2.0

The rock asphalt at N varies considerably in its content of bitumen. Mr. Arguelles found in a sample from the lower beds 61.85 per cent of total bitumen, while two samples from the upper part of the deposit, examined by Mr. Wells, yielded 6.30 per cent and 8.84 per cent of the total bitumen, respectively. The sample richest in bitumen contained only 0.13 per cent of paraffin scale. The strikingly lower paraffin content of the bitumens from outcrops D and N as compared with the bitumens from the other outcrops may be due to the fact that the bitumens at D and N have migrated through porous or broken rocks, while elsewhere the bitumens have simply occupied open spaces in the rocks. That is to say, the paraffin might have been removed by the filtering effect of the diffusion of the original petroleum through porous rocks.

SOURCES AND PROBABLE QUANTITIES OF PETROLEUM AND RESIDUAL BITUMENS

The source of the residual bitumens in Leyte is undoubtedly the petroleum with which they are associated. Natural bitumens are universally conceded to have their origin in petroleum, being formed through the elimination of the more volatile constituents and the concentration and metamorphism of the heavier hydrocarbons. The bitumens in Leyte form so nearly a continuous series from petroleum to solid coallike bitumen and are so like the base of the Leyte petroleum in their constitution that the relation of one to the other would be clear without the necessity of drawing analogies from what has been learned concerning other natural bitumens.

The source of the petroleum in Leyte is probably the Vigo shale, just as the Vigo shale appears to be the source of the petroleum in the Tayabas field, where the essential conditions are similar to conditions in Leyte. Possibly some of the Leyte petroleum originates in the Canguinsa, although the fact that petroleum and residual bitumens are found in the Canguinsa at present may be explained otherwise. In all the observed occurrences of petro-

leum and residual bitumens in Leyte there is none which could not have originated through the infiltration of petroleum from the Vigo shale. Samples of *Globigerina,* which were found in the Vigo shale in Tayabas and were rather doubtfully credited with the origin of the Tayabas petroleum in the previously cited report on that field, occur abundantly in the Canguinsa as well as in the Vigo in Leyte. If these little animals are really the ultimate source of the petroleum, then the Canguinsa must have yielded more petroleum than the Vigo. But the truth of this theory is not established. Nowhere, as a matter of fact, has *Globigerina* been observed in numbers sufficient to justify the idea that it is the source of more than a very limited quantity of petroleum.

That petroleum is present in the Vigo shale in Leyte as well as in Tayabas and in Cebu is a matter of common observation. Evidence has been cited in the descriptions of several of the occurrences in Leyte which indicates that the petroleum moved through the Canguinsa clay-tuff along fractures, bedding planes, faults, brecciated zones, and open fissures, but nowhere is there evidence that the petroleum permeates the clay-tuff itself. It is certain that the Vigo shale is petroleum-bearing, and while the Canguinsa sandstone may also be a source of petroleum, it is not unreasonable to assume that most of the petroleum and residual bitumens now found in the Canguinsa migrated into that formation from the underlying Vigo shale.

The possible relation of the intrusive rocks to the accumulations of petroleum which gave rise to the deposits of natural bitumen should be taken into consideration. Outcrops L and M consist of breccias very like the breccia produced by the Mount Tabeyta intrusion. At outcrop D there are breccias and concretions which appear to be related to hidden intrusions. Intrusive rocks are found below the outcrops at N in the neighborhood of a probable fault plane. It is true that in the immediate vicinities of the largest intrusions no petroleum nor bitumen is encountered at the surface, but at distances of from 2 to 3 kilometers from the center of Mount Tabeyta, which is itself something like 1 kilometer in diameter at its base and over 200 meters high, are several important outcrops. The larger number of the intrusions found are in the Vigo shale and do not reach the overlying rocks, a fact which makes it probable that in territory covered by the upper rocks, like the vicinities of most of the bitumen outcrops, other intrusions exist beneath the surface. The suggestion may be made, therefore, that the intrusions have driven petroleum from the beds penetrated—Vigo shale and pos-

sibly also Canguinsa clay-tuff—into the fractured and brecciated zones resulting from the intrusions.

There is no way of ascertaining what quantity of petroleum may be obtained from a petroleum field except by the actual drilling of wells, and speculation in advance of all exploration can have little value as an estimate. In the study of the Tayabas field it was observed that petroleum reached the surface near the top of the Vigo shale only, in a series of close-grained beds from 50 to 100 meters in thickness, and the inference was clear that if the petroleum were confined to these beds in which it appeared at the surface there could be little hope of a quantity of petroleum comparable with the yields of the larger fields in America. In other words, the porous beds necessary to serve as reservoirs for large petroleum accumulations are not extensive or, at any rate, not prominent, in Tayabas.

In Leyte the situation is similar, although petroleum appears to be present at horizons lower in the Vigo shale than are the seepages in Tayabas, and the quantity of petroleum represented by the various deposits of residual bitumens is much greater than there is direct evidence of in the surface indications in Tayabas. But the petroleum from which the bitumen deposits in Leyte are derived may have been driven from the petroleum-bearing rocks by the action of heat from intrusions, a process which would have removed petroleum from the Vigo shale or the Canguinsa clay-tuff very efficiently. Similar intrusions in the Vigo shale in Tayabas might have caused equally extensive surface showings. If the possible agency of intrusions in the concentration in Leyte of quantities of residual bitumens great enough to demonstrate the former presence of large volumes of petroleum be admitted, the presence of these bitumens does not prove that drilling would result in the recovery of equally large volumes of petroleum, even though the major part of the original supply is still held in the rocks. Drill holes simply permit the flow of petroleum and are most effective when they penetrate saturated, porous beds, while intrusions would have forced the petroleum out of the adjacent beds—porous or close-grained, saturated or only partly saturated.

It is improbable that wells drilled into the close-grained Vigo shale either in Leyte or in Tayabas will yield the large flows obtained in other fields from extensive lenses of porous sandstone. There is in Leyte, however, the chance that pockets of petroleum in the broken zone surrounding an intrusion (assuming that the intrusions have in reality been effective in concentrating the petroleum) may have been preserved by the sealing up of passages

through the overlying beds, and wells penetrating such zones might obtain larger flows than the undisturbed shale would yield.

The deposits of solid bitumens indicate the former presence of a large quantity of petroleum in the Leyte formations. But they indicate also the escape and consequent loss of much of the original supply. Just what proportion may remain is undetermined. When all is said and done, definite evidence as to the quantity of petroleum present in Leyte and in Tayabas will be obtained only by drilling test wells.

The evidence as to the quantity of solid bitumens present in Leyte is somewhat more definite, but here again lack of exploration makes impossible the exact estimates that are desirable.

The tonnage of deposits like those outcropping at A and B cannot be estimated in advance of exploration. The width of the fissure or vein at B as revealed in the floor of the shallow pit opened there is about 60 centimeters. The gilsonite veins in Utah, according to George H. Eldridge,[9] range in width from 45 centimeters to over 5 meters and contain a total quantity of more than 30,000,000 tons. While the vein at outcrop A in Leyte is thin, its width is of the same order of magnitude as the width of the veins in Utah. In Utah, however, the outcrops even of the small veins can be traced for several kilometers, while the vein at outcrop A can be followed a few meters only on the surface. Yet the vein at A may be found to be persistent underground, for it is well known that outcrops are usually obscure in the Philippines. The outcrop of the coal bed mined at East Batan, Albay, for instance, could be traced on the surface only a comparatively short distance, yet the workings in the mine ultimately proved an area of 50 or more hectares with the coal always regular and continuous. Only by exploration can the extent of the vein at B be ascertained. Without exploration there is in sight at the present time only a few tons of bitumen.

At C and D the quantity of bitumen in sight is insignificant, but no prospecting of the outcrops has been attempted.

Limited exploration on several outcrops in the region of E, F, and G has recovered only 100 tons or so of bitumen and has indicated that some of the deposits contain not much more than this quantity of material. The work has been only superficial, however, and it may be possible to follow the irregular bodies beneath the surface into deposits of larger proportions.

The outcrop at K has not been explored, but the surface indications promise little in the way of tonnage.

[9] *22d Annual Rept. U. S. Geol. Surv.* (1900–1901), pt. 1, 342 et seq.

The work on the outcrops at M and N has been too limited to prove the extent of the deposit. About 100 tons of the mixture of bitumen and clay-tuff has been mined. The surface conditions indicate a considerably larger deposit in this vicinity than in any of the foregoing. The thickness is greater, and outcrops are found over an area of fair dimensions. It is claimed by interested prospectors that exploration by drilling has proved a thickness of about 15 meters over an area 300 meters square. It is stated also that the same bituminous mixture is encountered beneath the surface in the town of Villaba at a distance of 800 meters north of the outcrop at L. The exploration of the deposits at L and M would be a simple and inexpensive undertaking, since the breccia of bitumen and clay-tuff appears to lie near the surface.

The quantity of rock asphalt at N undoubtedly is to be measured in thousands of tons. Although no exploration has been undertaken, the dimensions of the exposed face make it certain that there are present at least several thousand tons. If the vertical dimensions of the deposit and its dimensions at right angles to the exposed face are of the same order of magnitude as the revealed length of the face—suppositions which are by no means unreasonable—the total quantity of rock asphalt at N must amount to hundreds of thousands of tons.

THE UTILIZATION OF THE RESIDUAL BITUMENS

If petroleum is obtained commercially in Leyte, no problem arises as to its disposal. The Philippine market for petroleum products amounted to 3,641,078 pesos [10] in 1914, according to the import records of the Collector of Customs as shown in the following table:

TABLE IX.—*Imports of petroleum products into the Philippine Islands in 1914.*

Petroleum product.	Quantity.	Value.
	Liters.	*Pesos.*
Crude oil, including all natural oils without regard to specific gravity	1,689,108	48,360
Refined or manufactured oil, naphtha, including all lighter products of distillation	5,508,189	563,408
Illuminating oil	48,517,689	2,562,040
Lubricating and heavy paraffin oil	3,048,610	426,258
Residuum, including tar, and all others, from which the light bodies have been distilled	765,182	41,012
Total	59,528,778	3,641,078

[10] One peso Philippine currency equals 100 centavos, equals 50 cents United States currency.

If petroleum were available in quantity at a cost which would make it a competitor with imported coal as fuel, the present Philippine petroleum consumption would be multiplied. Inter-island steamships and the railroads would undoubtedly adopt oil fuel, and these factors alone would greatly increase the market for petroleum.

With the residual bitumens, however, the case is different. The rock asphalt from the deposit at N may prove valuable as a paving material. Two representative samples of the rock asphalt yielded 6.30 and 8.84 per cent of bitumen, respectively. A sample from the rich lower portion of the deposit contained 61.85 per cent of bitumen. Probably the average grade of material carries from 6 to 10 per cent of bitumen. The rock asphalt most widely used in Europe carries from 6 to 8 per cent of bitumen. Other rock asphalts carry from 10 to 12 per cent of bitumen, but are mixed with poorer materials for use. It is stated that a rock-asphalt pavement should contain from 7 to 10 per cent of bitumen.

One of the principal objections to rock asphalts has been the contention that the bitumen is usually insufficiently asphaltic in character to make a good binder in pavements. In the following table are analyses of the rock asphalt from the outcrop at N compared with analyses of sheet-asphalt pavement and with analyses of rock asphalts from Oklahoma, which have been proved to be of superior quality for paving:

TABLE X.—*Analyses of rock asphalts and sheet asphalts.*[a]

Source.	Total bitumen.	Petroleum.	Asphaltene.
	Per cent.	*Per cent.*	*Per cent.*
Outcrop N, Villaba, Leyte	8.84	56.0	44.0
	6.30	58.0	42.0
Sheet-asphalt pavement:	13.5	90.1	9.9
Muskogee	9.1	67.1	32.9
Oklahoma	11.0	78.1	21.9
Rock-asphalt pavements in Oklahoma	7.85	78.81	21.19
	10.10	72.65	27.35
	9.80	70.61	29.39

[a] First analyses by A. H. Wells, chemist, Bureau of Science. Other analyses are from Oklahoma Geological Survey Circular 5 (1913), 18.

The Leyte rock asphalt has more asphaltic constituents than the rock asphalt from Oklahoma, which is a superior paving material. Consequently no insufficiency of asphaltic compounds can be charged against the Leyte rock asphalt. It is even possible that it is too high in asphaltic constituents and will de-

mand fluxing with petroleum residuum as do the true asphalts. Paraffin, an ingredient which must be low in paving asphalts, and is objectionably high in some of the Leyte bitumens, is remarkably low in the Leyte rock asphalt, amounting to less than 0.5 per cent of the bitumen present. Thus the laboratory investigation of samples of the Leyte rock asphalt indicate that it could be used for paving. But the question is one which cannot be definitely answered except by actually laying an experimental pavement and observing its behavior under traffic.

If the rock asphalt proves to be a good paving material, there would be a market for it in the paving of city streets and important roads in the Philippines. The cost of quarrying the rock asphalt and bringing it to deep water should be small. The scarcity of really superior stone for macadam and the cost of the asphalt pavements which have already been laid in the Philippines make it appear that a suitable rock asphalt could be transported from Leyte to Manila and elsewhere at a profit to the quarry enterprise and with a saving in the cost of asphalt pavements. Consul-General George E. Anderson, at Hongkong, believes [11] that there is a possible market for asphaltic paving materials in oriental cities outside the Philippines. Such a demand might mean the profitable exportation of the Leyte rock asphalt.

Rock-asphalt pavements have been employed extensively in Europe, especially in France and Italy. In the latter country the production from 1904 to 1912 ranged between 108,000 and 191,000 metric tons, valued at an average of about 6 pesos per ton. In the United States rock-asphalt pavements have found less favor than in Europe, partly, at least, because of the cheapness of artificial asphalt from petroleum. Oklahoma rock asphalt is coming into use, however, and even in California, where artificial asphalt obtained from petroleum is abundant, 27,600 metric tons of rock asphalt, valued at 6.18 pesos per ton, were mined in 1913.[12]

Rock asphalt in pavements is laid like sheet asphalt. A concrete foundation is generally employed, and the rock asphalt, pulverized to maximum diameters of 1 centimeter, is heated to about 150° C. (considerably less than the temperature required for sheet asphalt), spread on the foundation with rakes, and rolled while hot. The wearing coat is about 5 centimeters thick after rolling.

[11] Daily Consular and Trade Report, June 9 (1914).

[12] Data taken from *Min. Resources U. S. Geol. Surv.* (1913), pt. 2, 539.

Both the physical characters and the chemical compositions of the other residual bitumens make them unfit for use in pavements. Materials of similar character are widely used in America and Europe for other purposes, however, and are more valuable than paving asphalt. The utilization of these bitumens in the Philippines is complicated by the restricted local market for the products made from them elsewhere. Their exploitation, therefore, if they are developed in quantity, must be preceded by the establishment of a market either locally or through exportation. The purposes for which they can best be utilized is a subject for chemical investigation, but the following list of possible uses for gilsonite and related asphaltic substances may be quoted:[13]

> The manufacture of black, low-grade brush and dipping varnishes, such, for instance, as are used on the various kinds of ironwork, and as baking japans; * * * for preventing electrolytic action on iron plates of ship bottoms; for coating barbed-wire fencing, etc.; for coating sea walls of brick or masonry; for covering paving brick; for acid-proof lining for chemical tanks; for roofing pitch; for insulating electric wires; for smokestack paint; for lubricants for heavy machinery; for preserving iron pipes from corrosion and acids; for coating poles, posts, and ties; for toredo-proof pile coating; for covering wood-block paving; as a substitute for rubber in the manufacture of cotton garden hose; as a binder pitch for culm in making brickette and eggette coal.

Some of these possible products would find no market locally, and chemical investigation may prove the Leyte bitumens unsuited for the manufacture of many of them, but it would also undoubtedly reveal other uses to which they might be put. The analyses already performed show that some of the bitumens are high in paraffin, a substance which is used locally in the manufacture of matches and candles and which could probably be exported at a profit, since it is worth in the crude state about 34 centavos per kilogram.

Another possible use for the Leyte bitumens and bituminous mixtures is suggested by the exploitation of the so-called kerosene shales in Scotland and in New South Wales. The Scotch shales yield upon distillation about 96 liters of crude oil per metric ton. The crude oil, upon fractionation, yields in turn 6 per cent of gasoline, 32 per cent of kerosene, 24 per cent of heavy oils, and 12 per cent of paraffin scale.[14] According to the distillation tests quoted on another page, 1 ton of the

[13] Eldridge, G. H., op. cit., 356.

[14] Lewes, Vivian B., Liquid and Gaseous Fuels. Archibald Constable & Co., Ltd., London (1907), 97.

mixture of bitumen and clay-tuff from outcrops L and M yields about 175 liters of crude oil containing 10 per cent of gasoline, 36 per cent of kerosene, and 52 per cent of heavy oils. The heavy oils and residue contain about 20 per cent of paraffin. Therefore the mixture from outcrops L and M yields nearly twice the volume of oil that the Scotch shales yield, and the oil obtained contains a higher proportion of the lighter, more valuable constituents. From the best shale in New South Wales more than 600 liters of crude oil per ton are obtained, but the average yield is much less than this figure. It might be found practicable to enrich the bitumen mixture from outcrops L and M in Leyte by additions of the pure bitumens from the other outcrops and so obtain more crude oil upon distillation. The distillation products from the rock asphalt at N are similar in character to those from the mixture at L and M, and although most of the rock asphalt contains too little bitumen to justify distillation, parts of it are much richer than the mixture from L and M. One sample from N, for instance, yielded almost 62 per cent of bitumen. Gasoline, kerosene, and heavy oils, whatever their source, would find a ready market in the Philippines.

It is concluded, then, that the natural bitumens in Leyte can be profitably utilized if they are developed in quantity.

SUGGESTIONS FOR EXPLORATION

The possibility of obtaining petroleum commercially in Leyte should be investigated further. My observations do not enable me to indicate the most favorable drilling sites nor even to state that the chances of success are great enough to warrant drilling. The venture might not prove attractive to private capital, but considering the immense industrial importance of petroleum to the Philippines, the Government might be justified in an attempt at development.

This recommendation that the Government undertake to explore petroleum deposits has already been made in the case of the Tayabas field. In view of the later investigation of the Leyte region a question arises as to which territory offers the better chance of success, which should be explored first, and whether or not both fields should be tested. The answers to these questions must await further geologic study.

It may be explained that petroleum is commonly found in porous beds, where it is retained by cover and floor of close-grained impervious beds after having been driven to the highest points to which it has access by the buoying-up effect of the

heavier, associated water. Differences in the elevation of a given bed are usually due to folding, and thus it is that petroleum has so often been encountered in the arches or anticlines of folds as to give rise to the term "anticlinal theory" to designate this interpretation of the principles of petroleum accumulation. Many other causes, of course, may result in the entrapping of petroleum in the higher portions of porous beds: for example, a dike of impervious rock may cut through beds tilted in one direction and confine petroleum migrating through the porous bed from below; or the same thing may be accomplished by the sealing of the pores at the surface of tilted beds by the residuum left from escaping petroleum so that the rest of the petroleum is retained. In its widest sense the anticlinal theory accounts for the petroleum accumulations in a majority of the productive petroleum fields.

Petroleum seepages occur along the anticlines both in Tayabas and in Leyte, indicating that the anticlines are points of accumulation in these fields as they are in Sumatra and Japan, in which countries large commercial productions are obtained from formations of the same age and general character as the Philippine petroleum-bearing rocks.

Intrusive rocks are generally considered as an unfavorable indication in connection with prospective petroleum fields, for the reason that by their intrusion these rocks break up and shatter the strata which they penetrate, destroying the original structure and permitting the escape of any accumulated petroleum. However, the history of the development of parts of the Mexican petroleum field, which has recently attained an enormous production, shows that in this one instance intrusive rocks have not been injurious, but have actually accomplished the concentration of the petroleum, displacing it from buried strata and providing a reservoir for its accumulation in the openings of the shattered zone surrounding the intrusion. Intrusions have become centers of accumulations, seepages occur near intrusions, and wells drilled in the vicinity of an intrusion have repeatedly been successful.

In determining whether drilling in Leyte is warranted and, if so, where test wells should be located, data should be sought which will tend to show whether the igneous intrusions have merely dissipated the petroleum or have also promoted the accumulation of petroleum under favorable circumstances; whether there are accumulations of petroleum in structurally favorable areas independent of the intrusions; or whether both these fac-

tors are effective in controlling the accumulation. To determine these points, a detailed geologic study should be made both in the vicinities of anticlinal structures and in the vicinities of intrusions in Leyte.

It appears from the preliminary study that anticlines across the crest of which the rocks above the Vigo shale remain in place—that is, have not been eroded—are more promising than the anticlines upon the limbs of which the Vigo shale is exposed. The anticline at outcrop D, for instance, has afforded less chance for the escape of accumulated petroleum because of the presence of a cover of Canguinsa clay-tuff across its crest than the anticline at I and J, where the upturned edges of the Vigo are exposed at the surface. The anticline between I and J must be considered with still less promise, if the igneous exposure at I proves to be a part of the base upon which the Vigo lies. Nevertheless the large exposure of Vigo shale lying to the east and south of Villaba should be gone over in detail, particular search being made for seepages, intrusions, porous beds, and faults.

The region between outcrop N and the barrio of Baliti, where both intrusions and anticlinal structure are indicated, should be studied. The regions inland from the several coastal indentations between Villaba and San Isidro should be prospected. Seepages of petroleum and outcrops of solid bitumen other than those already discovered probably exist, and fixing the position of such occurrences will facilitate geologic interpretation.

If petroleum has accumulated in anticlines independently of intrusions, the northern part of the peninsula of northwestern Leyte, where folds undoubtedly exist in which the petroleum-bearing rocks are protected by a splendid cover of Canguinsa and Malumbang strata, should include promising territory. This area, therefore, should receive careful attention.

If the petroleum accumulations prove to be related invariably to intrusive rocks, the territory surrounding the intrusions will be most valuable. The known intrusions should be examined in the light of this suggestion, and search should be made for other intrusions.

In prospecting for other deposits of solid bitumens, the area south of Campocpoc is most promising, including territory as yet unexplored between Villaba and Tabubunga. No solid bitumens have been found in the Vigo shale; accordingly search for these materials should be directed especially to the upper rocks, although with only the data in hand at present it would be unwise to disregard the Vigo shale entirely. The solid bitu-

mens, if not the petroleum, appear to be confined to regions where dynamic action has been comparatively severe, resulting in sharp folding, faulting, or intrusion. On the basis of this observation the foregoing recommendation of the southern part of the field is made.

Where petroleum-bearing rocks are exposed at the surface, as they are at I and J, shallow dug wells might be made to yield a small quantity of petroleum. Initial production in Japan and in Formosa came from dug wells. At any rate claim holders who lack capital for drilling might dig wells in this manner to answer the requirements for assessment work. Similar excavations on outcrops of semiliquid bitumen like those at D might also develop small flows of petroleum.

In exploring the deposits of solid bitumens, hand drilling should prove serviceable as supplementary to pits and tunnels. Drilling alone would be unreliable in deposits of bitumen mixed with clay-tuff like those at L and M. In tracing float bitumen to the original vein or deposit in place, open trenching might well be resorted to. Outcrops are obscure, and once a vein is found, it should be followed closely by excavation. The presence of faults may complicate the work of exploration.

SUMMARY

Several seepages of petroleum and a number of outcrops of residual bitumens derived from petroleum occur in the region of Villaba, Leyte, in easily accessible country. The containing rocks are of Tertiary and Quarternary age. The principal known occurrences are confined to an area 8 kilometers wide and 13 kilometers long. The petroleum appears to come from the Vigo shale, which belongs to the lower Miocene or Oligocene, while most of the residual bitumens are encountered in the Canguinsa clay-tuff, immediately overlying the Vigo. The various formations can be correlated perfectly with the rocks in which petroleum is found in Tayabas Province, and the two fields are very similar. Petroleum is obtained commercially from the same geologic horizon and from the same class of rocks in Sumatra, Formosa, and Japan. The total thickness of the bedded rocks is probably about 2,000 meters, and the petroleum comes to the surface at a horizon above the middle of the rock series.

The region of the outcrops and seepages in Leyte is sharply folded, and the lower strata, including those which are petroleum-bearing, are intruded by small bodies of andesite, some of which are domelike in shape. The distribution of the accumu-

lations of petroleum and of bitumens derived from petroleum appears to be governed partly by anticlinal structure and partly by the intrusions. The petroleum has a paraffin base and a large proportion of burning oils. The different bitumens are semiliquid, viscous, and solid and cannot readily be classed according to the recognized mineral types. They all contain paraffin and are clearly derived from the associated petroleum. They are found filling fissures along bedding planes and in pockets, impregnating porous limestone and sandstones, in mixture with fragments of unchanged clay-tuff near the present surface, as cements in breccias of mineral-impregnated clay-tuff or shale, and in cavities in concretions in the clay-tuff. The pure bitumens cannot be used for paving purposes, but would be valuable in the manufacture of other products. One large deposit of bituminous limestone, or rock asphalt, has been found which can probably be used as a paving material. Some of the deposits of bitumens appear to be of limited size, but others are very probably large enough to be of commercial importance.

No exploration has been carried on in Leyte, but there is enough chance of obtaining petroleum to justify a thorough geologic study and probably enough chance to justify drilling at favorable sites. The least-promising feature of the field from this point of view is the apparent lack of porous beds adequate in extent to serve as reservoirs for large accumulations of petroleum, but there are many thin beds of sandstones intercalated with the Vigo shale, and further study may prove the aggregate volume of pore space in these beds to be large enough to afford abundant storage capacity.

ILLUSTRATIONS

Plate I

(Photographs by Pratt.)

TEXT FIGURES

Fig. 1. Cylindrical concretion.

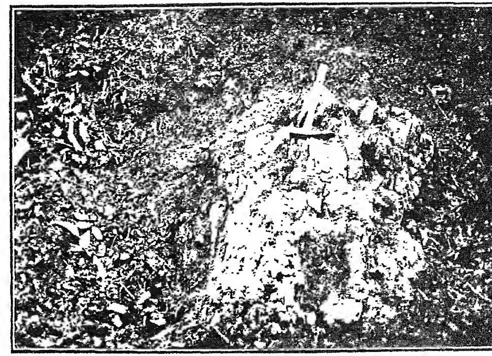


Fig. 2. Bitumen-cemented breccia dome.

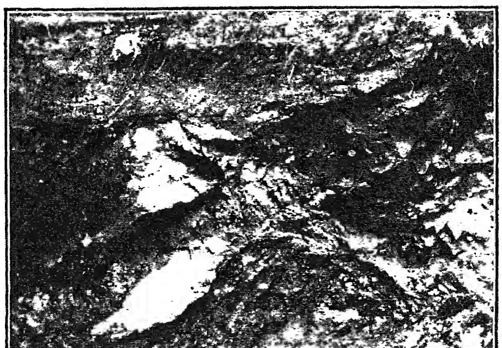


Fig. 3. Outcrop of bitumen.

Fig. 4. Outcrop of Vigo shale.

PLATE I.

ON THE OCCURRENCE OF PETROLEUM IN THE PROVINCE OF CEBU [1]

By Wallace E. Pratt

(From the Division of Mines, Bureau of Science, Manila, P. I.)

TWO TEXT FIGURES

HISTORICAL

The occurrence of petroleum in Cebu appears to have been first noted by the Spaniards about the year 1888. La Isla de Cebu,[2] a detailed geologic study by Abella, published in 1886, contains no reference to petroleum, but the same writer in La Isla de Panay,[3] published in 1890, in discussing a natural flow of inflammable gas which he encountered in Iloilo Province, states that shales which yield small quantities of petroleum had recently been discovered in Cebu.

The records of the Spanish inspectorate of mines show that application for the exclusive right to recover crude petroleum and to refine the same in the Philippines was made in 1893 by an Englishman, named Alfred White, who stated that he had discovered petroleum at Toledo, in Cebu, and that he wished to exploit other petroleum deposits on Negros and Leyte.

Becker [4] notes that petroleum is found at Asturias, Toledo, and at Alegria, on the west coast of Cebu, and refers to the Guia Oficial for 1898. Smith [5] visited Toledo and Alegria in 1906 and examined the petroleum prospects at these places. The observations which are embodied in the following notes were made recently during a number of short visits to Cebu for the examination of other mineral resources.

PETROLIFEROUS SHALE

A fine-grained, bluish gray shale, or clay-shale, which emits a slight odor of light oils and appears to be slightly petroliferous, is to be observed at widely separated places in Cebu and is probably of general distribution. This shale is exposed usually

[1] Received for publication April 23, 1915.

[2] D. Enrique Abella y Casariego, Rapida Descripcion de la Isla de Cebu. Madrid (1886).

[3] Descripcion de la Isla de Panay. Manila (1890), 125.

[4] Geology of the Philippine Islands, *U. S. Geol. Surv.* (1901), 107.

[5] *Far Eastern Rev.* (1907), 3, 9.

along streams, in steep walls to 10 meters high, with a massive or imperfectly bedded appearance. It is compact and fairly hard, breaking with a distinct conchoidal fracture and rarely parting along bedding planes. It occurs near the top of the coal-bearing rocks (Miocene) above the coal beds and the sandy shales and clastic rocks which constitute the greater part of the series, but below the uppermost limestone. This shale, which is conspicuous at Uling in central Cebu, and is found on Inayangan River in east-central Cebu and on Argao River in southeastern Cebu, may have been noted by Abella. From the results of distillation tests on similar shales from Tayabas Province it may be inferred that the petroleum content of this shale is too small to be of economic importance. It is more probable that the petroleum originated from organic matter in the shale itself than that it migrated to this shale from elsewhere.

PETROLEUM AT ASTURIAS

During a visit to Asturias in 1912 I was unable to obtain any information as to the existence of petroleum in that vicinity. No concession for petroleum at Asturias has been recorded. The only statement to be found in the literature is the reference by Becker to the Guia Oficial, which simply affirms that petroleum is found at Asturias.

PETROLEUM AT TOLEDO

On Calamanpao River near Iligan, a barrio of Toledo, are two oil wells, over one of which a steel derrick stands. Near by are a number of lengths of steel casings, parts of a horizontal engine, and a badly rusted boiler. The elevation at the wells is about 40 meters. A concession of 30 hectares was recorded for this locality in 1897 in the name of Cornelio Roberto Blair Pickford. This claim later came into the possession of Smith, Bell & Co., Limited, of Manila, who drilled the wells and control the property at present. Near the wells are pools of water, the surface of which is covered with oil. This film of oil suggests the presence of oil springs, but may be no more than seepage from the wells.

According to Smith [6] the wells were drilled in the year 1896 and reached a depth of 244 and 344 meters, respectively, operations having been interrupted by an insurrection. The wells have been partly filled with bamboo poles, and at present the casings are open for a few meters only below the surface. The

[6] Loc. cit.

well over which the derrick stands is evidently the deeper of the two. Three strings of casing, 12 inches (30 centimeters), 8 inches (20 centimeters), and 6 inches (15 centimeters) in diameter, respectively, are visible at the collar. Petroleum stands in the well at a level but little lower than that of the ground surface. The petroleum is buoyed up by a column of water below it, and probably fills only a short length of the casing, but enough is present to permit the collection of a dozen or more liters at any time. The other well, 50 meters distant, is cased with 8-inch (20-centimeter) pipe and yields oil in a similar manner and quantity.

A sample of petroleum was collected from one of these wells in 1913 and brought to Manila for testing. Mr. F. R. Ycasiano, assistant engineer of the Bureau of Science, conducted 4-hour test runs with a Diesel motor, using the Toledo, Cebu, and Borneo crude oils in alternate tests. The Cebu oil proved to be a highly desirable fuel and somewhat superior to the Borneo oil.

Table I shows the specific gravities and percentage yields of the distillation products from Toledo, Cebu, crude petroleum.

TABLE I.—*Distillation products from Toledo, Cebu, crude petroleum.*[a]

Product.	Specific gravity at 15° C.	Volume.	Distillation temperature.
		Per cent.	° *C.*
Crude	0.885		
Gasoline	0.762	6.2	to 150
Kerosene	0.832	42.32	150-300
Heavy oils	0.901	38.3	300-375
Residue		13.17	375

[a] Analysis by H. C. Brill, chemist, Bureau of Science.

The foregoing analysis shows a much heavier oil than the product obtained from the Bondoc Peninsula field in Tayabas Province, which yields more than 40 per cent of gasoline.

The geologic structure at the site of the Toledo wells is monoclinal as shown in fig. 1. The beds lie upon the flank of the older igneous complex, which forms the core of the island. The rocks which outcrop at the wells are sandy shales, fine-grained clastics, and sandstones overlying sandy conglomerates, with a general dip to the northwest at an angle of from 50° to 60°.

A volcanic tuff outcrops just north of the wells on Calamanpao River and lies stratigraphically above the position of the

wells in apparent conformity with the lower strata. It is a fine-grained, spongy, white rock, which breaks with a conchoidal or porcelanic fracture and is composed largely of minute fragments of volcanic glass. In its extension to the southwest the lower beds of the tuff grade into an increasingly coarse-grained volcanic agglomerate or breccia. A prominent hill, about 1.5 kilometers west-southwest of the oil wells and stratigraphically above (?) the beds which the wells pierce, consists of this agglomerate, the fragments in which are porphyritic andesite.

Overlying the tuff is the coralline limestone which fringes the entire Island of Cebu. In this locality it is 100 meters or more thick, consists principally of unconsolidated, imperfectly bedded coralline material, and dips about 35° northwest. Abella considered this limestone to be of Post-Pliocene age.

Below the horizon at which the wells are located the strata

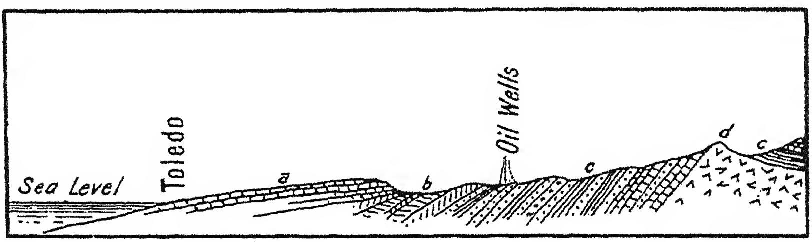


FIG. 1. Geologic section across strike of beds at Toledo, Cebu; partly diagrammatic. *a*, coralline limestone; *b*, tuff and agglomerate; *c*, Miocene shales, sandstones, conglomerates, and limestones; *d*, basal igneous complex.

include coarse sandstones, sandy shales, clastics, and limestone, in the order named from the position of the wells to the igneous basement. These beds have the same strikes but dip somewhat more steeply than those at the well site. The whole thickness of sedimentary strata on this flank of the cordillera appears to be at least 2,000 meters, the oil wells occupying a position near the middle of the series. There are no beds in this series which are conspicuously petroliferous, but some of the sandstones near the oil wells emit an odor of petroleum.

The oil wells must have pierced the petroliferous sandstones close to their outcrop. A well drilled to the northwest of the old site would encounter these sandstones under cover and should prove whether or not petroleum can be obtained from them in large quantities. It would be expected that any but a viscous oil would be dissipated from the open edges of the strata in a monocline dipping as steeply as do the beds at this point. All the rocks in the vicinity of Toledo which appear to offer any

chance of yielding petroleum could be tested by drilling a series of, say, three 600-meter wells along a northwest-southeast line across the strike of the beds.

PETROLEUM AT ALEGRIA

A fairly strong petroleum seep exists at the head of Malbog Creek near the town of Alegria. As early as 1897 a concession was recorded in the name of Smith, Bell & Co., Limited, for a petroleum claim of 150,000 square meters at Talayong, Alegria, and it appears that this claim covers the petroleum seep on Malbog Creek.

Alegria is on the western coast of southern Cebu, and the mouth of Malbog Creek is about 2 kilometers north of the town. The seep is at an elevation of about 365 meters and is about 2.5 kilometers from the coast. Southern Cebu generally is covered with the recent coralline limestone beds; only in

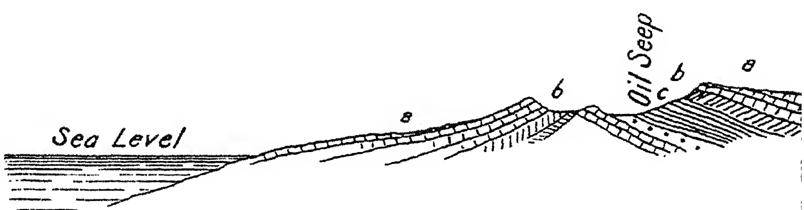


FIG. 2. Geologic section across strike of beds along Malbog Creek, Alegria, Cebu. *a*, coralline limestone; *b*, volcanic tuff; *c*, Miocene shales and sandstones over limestone.

small areas are the underlying rocks exposed. Fig. 2 represents a section across the strike of the beds and shows the rock succession and structure at the head of Malbog Creek. The petroleum reaches the surface through beds of blue clay or shale and is identical in appearance with the Toledo oil. The oil seeps directly from blue clayey shale in the wall of a ravine, and there is usually a small pool of oil and water at the seep. Blue shale, brown sandy shales, sandstones, and soft light-colored tuff are exposed near the seep with a thickness of about 100 meters beneath a capping of perhaps 150 meters of coralline limestone. The tuff is less conspicuous than at Toledo. The general strike is north 20° east; and an anticlinal fold is indicated by the dips. In the crest and eastern limb of this fold the beds are standing on edge and appear to be considerably broken up. The first limestone outcrop to the west of the oil seep appears to dip to the east, and must, therefore, pass beneath the shale from which the oil seeps. The presence of a

similar limestone at this horizon was not detected at Toledo. Placing this limestone in the eastern limb of the fold implies faulting in the plane of the anticlinal axis with an accompanying elevation of the eastern limb.

The petroleum seep at Malbog appears to be at a higher stratigraphic position than the oil encountered by the wells at Toledo; possibly, therefore, petroleum-bearing rocks at Malbog exist, a horizon lower than the seep, and petroleum migrates upward through the broken strata in the crest of the anticline.

The possibility of obtaining petroleum in quantity at Malbog could best be tested by drilling a series of wells along a west-northwest line across the crest of the fold. The structure appears to be favorable except that the anticline is rather sharp, and the presence of petroleum is demonstrated by the seepage, although there is no data as to the probable quantity. The vicinity of the Malbog seep is difficult of access; the narrow valley and the steep gradient of the creek, together with the elevation to be attained, would make transportation difficult and expensive.

ILLUSTRATIONS

TEXT FIGURES

THE PHILIPPINE

JOURNAL OF SCIENCE

A. CHEMICAL AND GEOLOGICAL SCIENCES
AND THE INDUSTRIES

VOL. X SEPTEMBER, 1915 No. 5

THE PERSISTENCE OF PHILIPPINE COAL BEDS [1]

By WALLACE E. PRATT

(From the Division of Mines, Bureau of Science, Manila, P. I.)

THREE TEXT FIGURES

Coal was discovered in Cebu as early as the year 1827, and within the next thirty years practically all the more important Philippine coal fields had become known. The Spanish Government made repeated attempts to develop an industry in coal mining both by fostering private enterprises and by undertaking to exploit some of the deposits in the name of the state itself. Similarly the American Government has sought to establish coal mining. Coal is one of two mineral products which may be exported from the Philippines free of duty; a tax must be paid on imported coals; coal-mining companies have received special favors at the hands of the Government even to the extent of financial assistance; and the United States Army opened a coal mine on its own account. Yet in spite of the long lapse of time since coal was discovered in the Philippines, and in spite of the many attempts at coal mining, no coal is produced in the Philippines to-day.

There are several good reasons for this state of affairs. Perhaps the greatest difficulty is that the coal is not of superior quality. Black lignites and subbituminous coals make up the greater part of the Philippine coal resources. Some of the coal fields are inaccessible. The roof and floor of the beds are soft and require close timbering. The coal is liable to spontaneous combustion, both in the mine and in storage. But the obstacle which has stood most directly in the way of developing coal mines is the discontinuity of the beds.

[1] Received for publication June 25, 1915.

Practically every attempt at prospecting has had to contend with the difficulty that the tunnels ran out of coal sooner or later under circumstances which made it difficult to decide whether the coal bed had been faulted or had failed by pinching out. It will readily be understood that a nearly vertical fault, more or less parallel to the strike of an inclined coal bed, might so displace the coal on either side of the fault plane that the bed would appear to pinch out gradually.

The true nature of the discontinuities in Philippine coal beds cannot be determined by geologic study alone. Outcrops are notoriously unreliable where the surface relations are so obscured by slides, by talus, and by the growth and decay of heavy vegetation, as they are in the Philippines. In certain individual cases it is clear that beds have been faulted, and less commonly unmistakable evidence that the original bed was of restricted lateral dimensions is to be found in gradually decreasing thicknesses along outcrops. But to decide which is the common cause of nonpersistence and usually to decide which factor is responsible in a particular case, underground exploration is necessary.

The exploration which has been carried out in the past throws some light on this problem, and it seems desirable to bring the results together for comparison and study. The work of exploration having been restricted to a few localities, the study cannot be made exhaustive, but an attempt to interpret the data which are available should be useful as a guide to future exploration.

The Spaniards performed and recorded the results of a great deal of exploration in coal beds, and their works should be reviewed briefly in this connection.

About the year 1874 an association called "La Paz" was organized to exploit certain deposits of coal which outcrop in the vicinity of San Esteban, a barrio of Bacon, Sorsogon. The outcrops appear to represent several beds, but the principal work was confined to a single bed, which, according to José Centeno, an engineer in the Spanish mining inspectorate, varied in width from 4 to 8 meters. All of the beds are nearly vertical and strike about north 20° west. The coal lies near the base of the Tertiary sedimentaries, and at the western edge of the sedimentary area—below the coal—there are outcrops of holocrystalline rocks which probably are part of the base upon which the beds were laid down.

The workings executed by the La Paz association, according to Centeno, included 6 shafts varying in depth from 22 to 34 meters and 5 galleries and crosscuts aggregating 66 meters in

length. Ramon Marty, an engineer employed by the company, states that 130 meters of gallery were driven at a level 11 meters below the surface and 188 meters of gallery at a level of 24 meters below the surface, beside the 6 shafts mentioned by Centeno. No faults were encountered, but the width of the coal varied from 4 to 8 meters, and there were zones near the surface in which the coal was broken and contaminated with fragments from the walls. Marty observed that the deepest workings were in good, solid coal and concluded that the broken condition of the coal was superficial only.

The coal was considered to be of excellent quality, 200 tons of it having been used for steaming tests by the Spanish navy. It was admitted, however, that the fuel tended to disintegrate, or slack, upon exposure. Both Centeno and Marty thought that mining could be carried on successfully and expressed no doubt as to the adequacy of the tonnage probably available. Nevertheless, very little was accomplished subsequent to the date of the reports quoted above. The company, La Paz, failed, apparently because of a lack of capital, and the mines were abandoned.

I visited the old mines in 1910, and while nothing remained of the former workings I found several outcrops, upon one of which a short tunnel had recently been driven. This bed is vertical and strikes north 20° west; its full width was not revealed but must exceed 2 meters. The tunnel was about 10 meters long and entirely in coal, neither wall being exposed. The coal appeared to be much contaminated with clay along fractures and in inclosed blocks or horses.

It may be concluded that the coal at San Esteban (designated variously as the Gatbo coal, the Sugud coal, and the Bacon coal) shows evidence of faulting in the broken condition of parts of the beds. The variation in width, also, may be due to the movements which caused the faults or it may be due to irregularities in deposition. The testimony of the Spanish engineers that conditions improved with depth suggests that faulting, not irregular deposition, is really the cause of the nonuniformity encountered, and the exploration so far as it goes indicates persistent coal beds.

Spanish engineers, also, directed important explorations of coal beds at Danao, Compostela, Guilaguila, and Uling in the Province of Cebu. The workings at Danao (barrio of Camansi) aggregated several thousand lineal meters and perhaps 10,000 square meters of rooms. Three or four different beds appear to have been explored, the thickness of which is from 0.5 to 1.5

meters on an average. A number of faults were encountered, and with few exceptions the coal was not recovered beyond the faults. On the other hand, the beds are fairly constant in thickness, and no evidence of irregularities due to the character of the original deposition is recorded.

At Compostela, also, numerous tunnels were driven and rooms were opened, the work done being about equal in the aggregate to that at Camansi, Danao. Two beds were exploited, both of which were regular and in the neighborhood of 1 meter in thickness. Two faults were encountered, one of which was of minor importance and caused little trouble, while the other cut off the coal so effectually that it was not again located. The sketches in fig. 1, taken from annual reports of Enrique Abella y Casariego, chief inspector of mines at that time, illustrate the effect of the smaller fault.

The coal is of the same character at Camansi and Compostela and ranks as a superior subbituminous coal. It was used satisfactorily as a steaming coal. The attempts at mining encountered difficulties on account of faults, but did not reveal any evidence of the pinching out of the beds, even though they were not of great thickness.

Spanish mining at Guilaguila, on the other hand, demonstrated that a bed of coal from 1 to 2 meters in thickness changed its character within a short distance to a series of thin layers intercalated with rock. However, the deposits at Guilaguila are known to overlie very closely the basement upon which the coal-bearing rocks were deposited, and it is not surprising that the conditions for deposition were rapidly changing and inconstant. The work at Guilaguila was carried on by the Spanish Government about the year 1853.

At Uling, Cebu, the Spaniards executed their most valuable work of exploration. There are several (probably five) beds of coal outcropping on the eastern slope of Mount Uling and dipping at an angle of from 30° to 40° west-northwest into the mountain. One of these beds, the outcrop of which is about 100 meters vertically above the level of the base of the mountain, is 5 meters thick at the surface. Doña Margarita Roxas, a most energetic woman, undertook the exploitation of this coal bed about 1860. She built 15 kilometers of mountain road extending from Tinaan on the coast to Alpaco, where she was carrying on other exploratory work, and thence north to Mount Uling. Having discovered by openings on the outcrop that the large bed was faulted near the surface, but that the faulted coal was intact and continuous for some distance beyond the fault, she determined

upon the excavation of a transverse drainage tunnel from the lowest practicable point to the extension of the large vein at depth.

This tunnel was driven through shale and sandstone a total distance of 647 meters and actually reached the large bed. But shortly after its completion the lady whose enterprise was re-

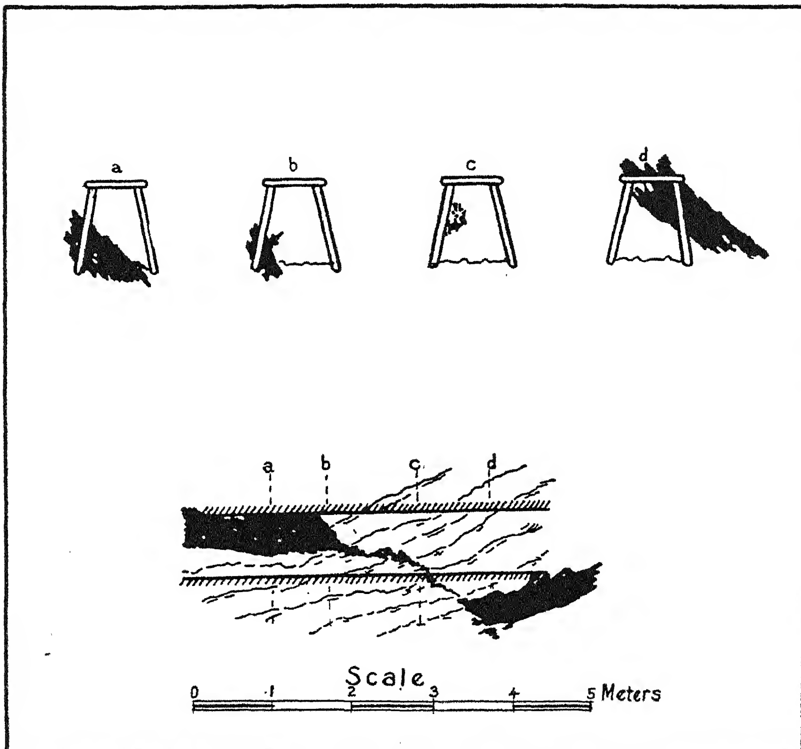


FIG. 1. Plan of Esperanza gallery at Compostela coal mine, Cebu, showing its passage through a fault, with sections across gallery at *a*, *b*, *c*, and *d*.

sponsible for the successful termination of the undertaking, which in that time must have been very difficult, died, and her work was allowed to fall to ruin. The tunnel encountered three other smaller beds of coal before it finally reached the large bed, and these results were carefully recorded by the engineers of the Spanish inspectorate. Abella estimated that a minimum quantity of 600,000 tons of coal was developed with reasonable certainty by this work, and the persistence of the large bed was

proved for a distance of approximately 200 meters down the dip and 150 meters along the strike.

Nevertheless the fact that the enterprise was abandoned just when its success seemed assured and was never resumed made the records appear questionable to American interests which came into control of the Uling field recently, and exploration was renewed to verify their correctness.

The recent exploration at Uling, which was conducted under my supervision, began with a slope entry on the 5-meter outcrop. This slope followed the floor of the bed for a distance of about 20 meters from the intersection of the bed with the surface, where a fault was encountered. This fault is parallel to the strike of the coal, but dips in the opposite direction—that is to say, the coal dips about 35° westward, while the fault dips about 30° eastward. The coal is truncated sharply along the fault,

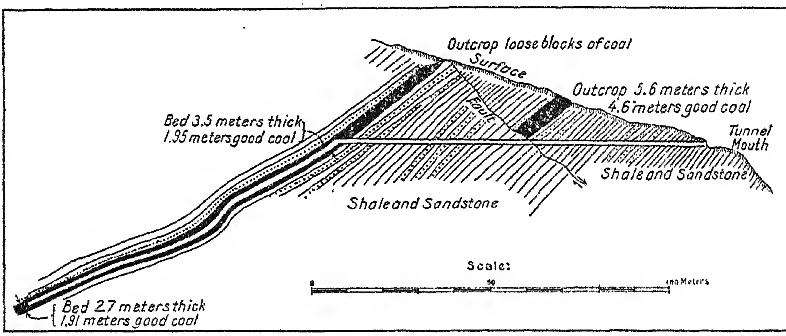


FIG. 2. Sketch, showing in section exploration work on a 5-meter coal bed at Uling, Cebu.

and there is little evidence of drag or movement along the fault plane. It was fairly clear, however, assuming that a normal fault had caused the displacement, that the continuation of the coal beyond the fault would be encountered by following the fault upward; in other words, the outcrop coal dropped along the fault.

It was decided to do no more work on the slope because of the inconvenience entailed in changing the grade from the fault plane forward, but instead to drive a new tunnel from a point about 50 meters farther north along the outcrop. This tunnel was driven so as to drain itself, and its portal was located about 10 meters lower than the outcrop. The fault plane was intersected at 48 meters from the portal, and at 121 meters the tunnel reached the coal bed beyond the fault. The last 20 meters of the tunnel were in sandstone and shale which showed no

evidence of fracture or displacement, but nearer the mouth, and especially in the vicinity of the main fault, the rocks were disturbed, slickensided, and broken. It is estimated that the coal had been displaced by this fault through a distance of about 40 meters measured along the fault plane.

Once having reached the coal beyond the fault, the tunnel was advanced as a stope (driven in parallel) on the full dip of the bed and carried 98.4 meters farther when old workings were encountered (fig. 2). It was concluded that the old workings probably had been driven up the dip from the face of the long Spanish transversal tunnel which, therefore, must have reached the bed as the records show. Unfortunately it became necessary to suspend the exploration at this point, although the results of the work so far completed had been fairly satisfactory.

At the outcrop of the faulted block the bed has a thickness of 5.60 meters between roof and floor, both of which are sandy shale and sandstone. About 4.75 meters of this is coal, of which 4.6 meters could be removed economically in mining. There are several parting planes, and there is one narrow parting of carbonaceous shale. About 0.2 meter of carbonaceous shale near the middle of the bed, and 0.6 meter of carbonaceous shale and thin coal at the bottom, would have to be removed as waste. In the driving of the tunnels the middle coal was mined by removing the central layer of carbonaceous shale. This permitted the upper coal as high as the parting to fall, after which the lower coal was taken up down to the lower parting.

The changes which the bed manifested as the work advanced are shown clearly in the accompanying sections (fig. 3). The bed where first encountered beyond the fault is only 3.5 meters thick between floor and roof and contains only 1.95 meters of coal. At the face of the slope, farther down the dip, the bed is still thinner—2.7 meters between floor and roof—but the thickness of the coal is maintained fairly well at 1.91 meters. Thus, while the general tendency is toward a gradually reduced thickness of the bed, the coal itself suffers little diminution below the position of the fault and becomes freer from intermixed shale. The only evidence of disturbance beyond the first fault was a slight roll, undoubtedly the result of a movement too restricted in extension to cause a true fault. However, the conditions of deposition appear to have varied alarmingly within a short distance, and the desired constancy is not proved.

The outcrop of this bed of coal can be traced but a few meters. Yet a kilometer away along the strike exploration was started on two other outcrops adjacent to each other, each of

which revealed 2.75 meters of coal. The work at this point encountered a fault after an advance of 13 meters in the coal. All work was suspended before the ground beyond the fault could be explored, and the true relation of these outcrops to the outcrops farther south remains undetermined.

The Uling coal appears from the foregoing to have undergone faulting which, however, is not serious enough to prevent mining. Evidence of inconstant conditions of deposition is brought out

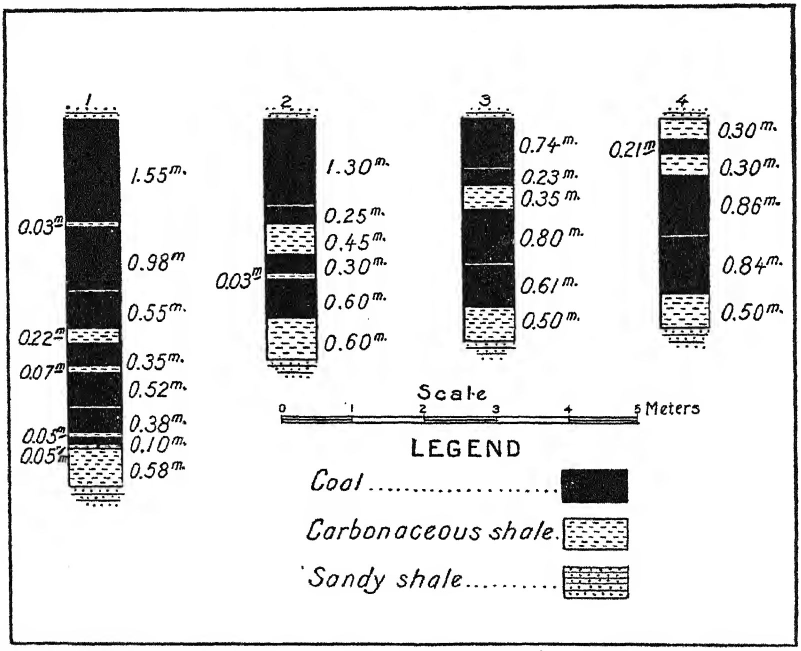


FIG. 3. Sections across 5-meter coal bed at Uling, Cebu. 1, cut section of outcrop of faulted coal; 2, section 10 meters beyond fault; 3, section 58 meters beyond fault; 4, section 84 meters beyond fault.

by the exploration, and the persistence of the coal beds over large areas is questionable. Yet it is not established that the bed has actually pinched out anywhere, and it is entirely possible that further exploration will prove tonnages adequate for commercial exploitation.

The Uling coal is slightly inferior to the Danao and Compostela coal, but is a valuable fuel, especially if it could be used for purposes such as cement burning, where it would be dried and pulverized before combustion.

The most thorough exploration of Philippine coal fields by

Americans was carried out on Batan Island, Albay Province. The western half of this island was reserved by the United States Army for the purposes of coal mining. On the eastern end of the island the East Batan Coal Mining Company developed a mine which yielded from 20,000 to 30,000 metric tons of coal annually for several years. The work of the United States Army demonstrated that faulting was a serious factor in the nonpersistence of the coal beds on the reservation, while the commercial mine at the other end of the island proved the existence of a bed of considerable dimensions with no evidence of faulting and but little indication of inconstant conditions of deposition.

Part of the exploration at the Army mine consisted of diamond-drill work. The results of the drilling are very confusing and difficult of interpretation. A large proportion of the different holes drilled yielded no core because of the softness of the rocks penetrated, and it is probable that the records of strata encountered are faulty on this account. One drill hole, according to its record, penetrated 11 distinct beds of coal, yet it is impossible to correlate these beds with the results obtained in adjacent holes.

The mine workings yielded more definite information. An opening on the Big Tree bed in the upper part of the coal-bearing rocks advanced 14 meters in coal which lay about horizontal and was 2.8 meters thick. For 10 meters the bed was perfectly regular, but within the next 4 meters it decreased in thickness, the floor rising abruptly in steps to about 30 centimeters. The work was abandoned without any attempt to proceed beyond the evidently faulted zone. Other openings of limited extent encountered faults in much the same way.

More important work was performed at New Number 5 mine, in the base of the coal measures. A slope was driven through rock to intersect two beds the presence of which was indicated in adjacent drill holes. The beds appeared to be parallel to each other and to dip at an angle of about 35°. The upper bed was first encountered, and the slope was continued as a drift along the strike of the bed for a distance of 60 meters. Throughout this distance the bed was irregular and showed considerable evidence of squeezing; at the end of the drift the coal was lost along a fault. A horizontal crosscut was driven to the lower bed through the intervening rock strata, a distance of about 10 meters. A drift on the strike of the lower bed from the end of this crosscut, parallel to the drift on the upper bed and at approximately the same level, advanced 50 meters to a fault,

probably the same one which had been reached in the upper bed. From the face of the drift on the lower bed an opening was now driven up the dip, which gradually flattened, until the bed became horizontal at a distance of 20 meters and then gradually reversed its dip, thus defining an anticline. Along the crest of this anticline another drift was started parallel to the original strike-drifts. This drift progressed a distance of about 100 meters in regular coal and encountered no fault, although it advanced far beyond the line of the fault which had displaced the same bed on the limb of the fold. Moreover cross entries were driven down the dip to the right and left, and the persistence of the coal was proved to a point directly in the line of advance of the faulted drift on the limb of the fold.

At this stage of the work exploration was suspended and has never been resumed. All the advancing faces were in coal varying in thickness from about 2 meters on the crest of the anticline to 1 meter at a distance of 30 meters down the dip on either side. The coal is of superior quality, although somewhat crushed by the folding pressures. It appears that a fault had been avoided in this case with no great difficulty, and the exploration, although incomplete, is encouraging. However, the quantity of coal actually proved by this work cannot be placed at more than 10,000 metric tons.

The mine of the East Batan Coal Mining Company, situated on the eastern end of Batan Island, constitutes the most extensive coal exploration performed by Americans in the Philippines. This mine developed a 1.5-meter bed of coal over an area 1,100 meters long and 400 meters wide. The main entry was 500 meters in length, and one of the butt entries was 800 meters in length. All faces were in coal, and the bed was absolutely regular. A 7-centimeter parting, 45 centimeters from the roof, was maintained everywhere without variation. The only change in the character of the coal was noted in the workings farthest advanced to the west. At this point balls or lenses of hardened mud, containing pyrite, made their appearance in the coal. The company suspended operations for financial reasons and not because of any lack of coal in the mine. The East Batan coal is objectionable as a steaming fuel, because of its low calorific value and its tendency to slack, or disintegrate, in storage.

In summary, the exploration of Philippine coal beds may be said to show that the continuity of the coal is frequently broken by faulting; that by careful work the coal can usually be relocated beyond the faults without much difficulty or expense;

and that evidence of nonuniform conditions has been obtained in some cases, but that nowhere have large beds been shown to pinch out entirely by reason of the limited area of the original deposition. It is to be noted that the coals of higher quality are mostly faulted and that the lower grade coals are most regular. This is a condition which would be anticipated, since all the coals are of approximately the same age and only by more or less violent dynamism have the removal of water and the increase in the proportion of fixed carbon necessary to improve the quality been accomplished.

Judging from past experience, then, the development of Philippine coal fields must contend with minor faulting and the possibility of varying thicknesses of coal due to irregular original deposition.

ILLUSTRATIONS

TEXT FIGURES

GEOLOGIC RECONNAISSANCE IN CARAMOAN PENINSULA, CAMARINES PROVINCE [1]

By WALLACE E. PRATT

(From the Division of Mines, Bureau of Science, Manila, P. I.)

ONE PLATE AND 2 TEXT FIGURES

CONTENTS

INTRODUCTION

At the time the field work was performed for a geologic reconnaissance of southeastern Luzon,[2] it proved to be almost impossible to study the inaccessible region of Caramoan Peninsula except from a distance. In March, 1914, I had an opportunity to accompany a party from the Bureau of Forestry into this little-known area and to obtain general data as to its geologic constitution, thus extending proportionately the geologic reconnaissance map of Luzon Island. The accompanying topographic map (fig. 1) of Caramoan Peninsula was made by Arthur F. Fischer and Raphael Medina, foresters, Bureau of Forestry, in company with whom I worked, and is based upon Coast and Geodetic Survey charts.

GEOGRAPHY

Caramoan Peninsula, jutting toward the northeast from the southeastern peninsular portion of Luzon, forms a distinct physiographic province. The region is mountainous and of extreme relief. Roth [3] and von Drasche [4] quote Hochstetter's opinion

[1] Received for publication June 21, 1915.

[2] Adams, G. I., and Pratt, W. E., *This Journal, Sec. A* (1911), 6, 449 et seq.

[3] Roth, Justus, Ueber die geologische Beschaffenheit der Philippinen (1873), 333–354.

[4] Drasche, R. von, Fragmente zu einer Geologie der Insel Luzon (Philippinen). Wien (1878), 39.

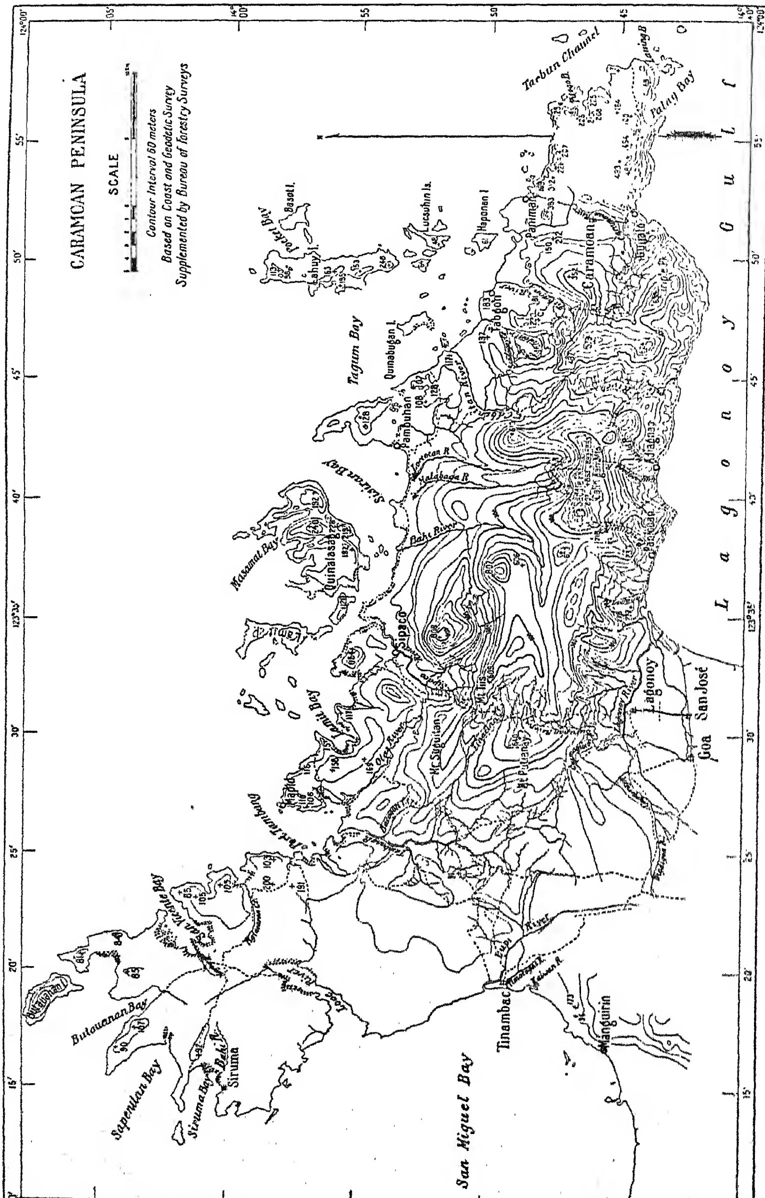


Fig. 1. Topographic map of Caramoan Peninsula, Camarines.

that Caramoan Peninsula was formerly an island and had been joined to the mainland of Luzon by deposits built up through eruptions of Isarog Volcano. The correctness of this conclusion is supported by the evidence of my reconnaissance work. Geologically Caramoan Peninsula is related to Catanduanes Island farther to the east rather than to the mainland, and the neck which connects the mass of the peninsula with the mainland consists of volcanic ejecta from Mount Isarog, younger in age than the rocks of the peninsula proper. The area is elongated in a west-northwest direction parallel to the main structural lines and contains approximately 600 square kilometers. The higher elevations, culminating in Saddle Peak (elevation 1,031 meters) in the Calinigan group of mountains, lie in the southern part of the peninsula, but extend west through the central portion. Mount Putianay, one of the prominent westernmost peaks, displays a white scar near its summit, which makes it conspicuous from the direction of the town of San Jose. The eastern end of the peninsula is rugged, but the hills attain only moderate elevations. The northern coast and the outlying islands are low and are fringed at places with swamps. The principal drainage systems discharge on the northern coast; no large river has developed so as to control the topography, but a series of short streams with tidal lower courses serve to carry away the run-off from an exceedingly heavy rainfall.

The peninsula is very sparsely inhabited, and a splendid forest covers its western half. The town of Caramoan near the eastern end of the peninsula was formerly larger than it is at present, and the forest has been cleared from much of the surrounding country. The forest yields a great deal of bejuco, a rattan used for binding hemp; the bejuco industry together with hemp planting and fishing are the principal industries. Some of the small islands to the north of Caramoan have been planted to coconuts, and the young groves are beginning to yield returns.

The southern coast of Caramoan Peninsula is regular and is bounded by straight lines; within a short distance from the shore the sea attains depths of 900 meters. The northern coast, in contrast, is sinuous, with numerous indentations, and the adjacent sea is shallow. Adams[5] has already pointed out the existence of a submarine shelf in this vicinity dotted with eminences which rise above sea level as small islands.

[5] Op. cit., 456.

GENERAL GEOLOGY

The greater part of Caramoan Peninsula consists of metamorphic rocks. Sedimentaries form the low-lying eastern end, and volcanics occur along the northern coast, but the conclusion that the central part of the peninsula is probably andesite, recorded in the reconnaissance already referred to, is in error. The rocks have been grouped as follows in the probable order of increasing age:

1. Alluvial and littoral deposits.
2. Isarog volcanic agglomerate and tuff.
3. Pliocene tuffs, flows, and agglomerates.
4. Tertiary sedimentaries } contemporaneous.
5. Metamorphic sedimentary rocks } contemporaneous.
6. Basal igneous complex.

The distribution of these formations is indicated on the accompanying geologic map (fig. 2).

ALLUVIAL AND LITTORAL DEPOSITS

Alluvial plains are developed over limited areas along the rivers at the town of Caramoan and the barrio of Parubcan. A larger area of mixed alluvial and littoral deposits is encountered in the vicinity of Lagonoy. These deposits are composed of surface detritus from the rocks of the various formations. The alluvium at Caramoan is largely clay and sand from the sedimentary series, while at Parubcan, where metamorphic rocks have been degraded, there is a larger proportion of gravel. At Lagonoy sand, clay, and gravel have been derived from the volcanic tuffs and agglomerates flanking Mount Isarog. Possibly some of the fragmental volcanic ejecta was thrown out late enough to have been interbedded with the recent alluvium. In the northeastern and northern parts of the peninsula there are mud flats largely covered at high tide, but there is little alluvium above sea level.

ISAROG TUFFS AND AGGLOMERATES

Mount Isarog is clearly an extinct volcano from which both flows and fragmental ejecta, uniformly andesitic in character, have been extruded in the past. The flows and the fragments in the agglomerates are porphyritic rocks with phenocrysts of calcic feldspar in a brownish, pumiceous groundmass. Many of the fragments in the agglomerate are partly rounded, so that the rock is in part a conglomerate of volcanic materials rather than a true volcanic agglomerate. The tuff, consisting of fine fragments of the same character as the flows, forms a cement

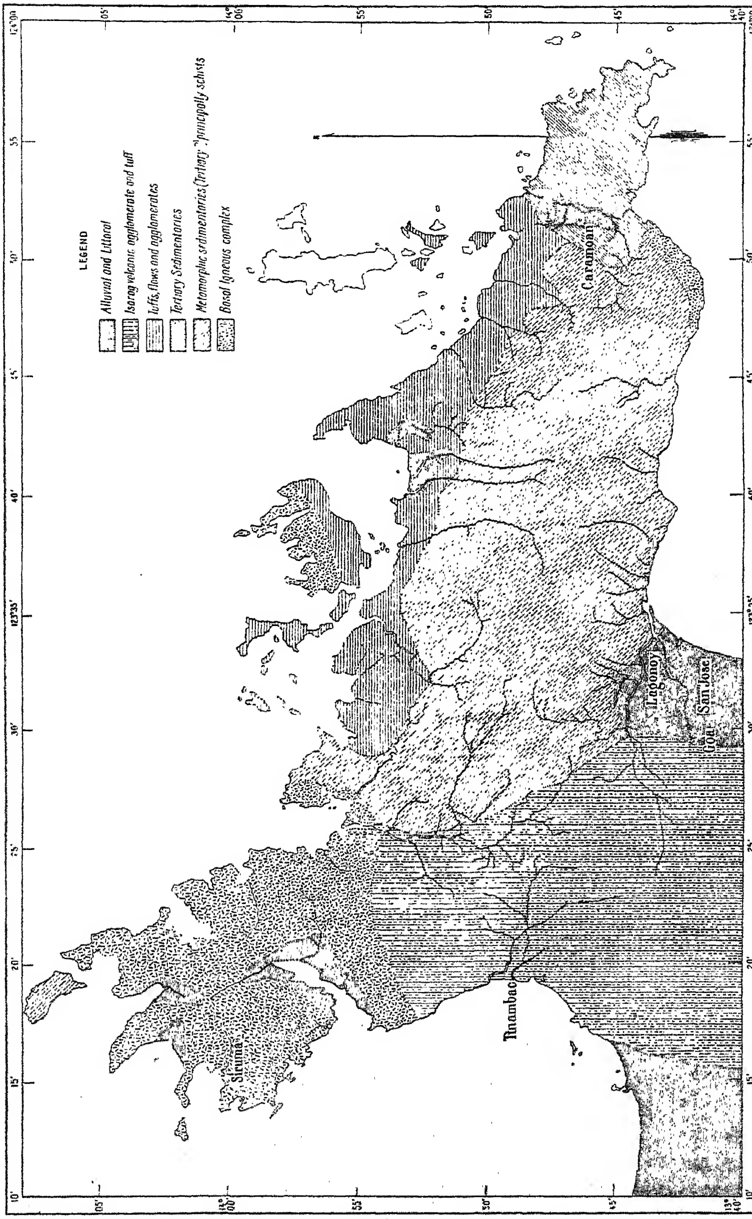


FIG. 2. Geologic reconnaissance map of Caramoan Peninsula, Camarines.

between the pieces in the agglomerate, but apparently does not occur as beds of exclusively fine-grained material. Part, at least, of the ejecta from Isarog is water-laid, but the formation is not bedded at any of the observed exposures. The series extends to the north as a veneer of gradually diminishing thickness over the metamorphic rocks.

Isarog Volcano belongs to a period older than the volcanic peaks to the south of it in Albay, one of which, Mount Mayon, is still active. It is probably younger than the tuffs and flows on the north coast of Caramoan, inasmuch as the latter are interbedded in part with the upper beds of the Tertiary sedimentaries, while the original distribution of the material from Isarog appears to have been influenced somewhat by the existing topography.

PLIOCENE TUFFS, FLOWS, AND AGGLOMERATES

The tuffs, flows, and agglomerates in the northern part of the peninsula are distinguished from the Isarog formation because of their probably greater age, their different character, and the complete segregation of the two formations in distribution. The northern series of volcanics consists of compact, perfectly bedded tuffs, tuff-sandstones, and intercalated, sheetlike flows, all of which are andesitic in character. In the region of the contact between this formation and the sedimentaries at the eastern end of the peninsula there are beds of limestone containing fragments of tuff in a series of strata which have also been pierced by domelike or pluglike intrusions of andesite and andesite-agglomerate. The series of tuffs, flows, and agglomerates is at least 100 meters thick. It lies nearly horizontal and forms low, grass-covered hills along the coast, but extends inland only to the base of the mountains.

TERTIARY SEDIMENTARIES

The sedimentary rocks in eastern Caramoan are a succession of limestones, shales, conglomerates, and fragmental or clastic sandstones. A single thin bed of coal is intercalated with the shales and sandstones. The thickness of the sedimentary series is undoubtedly not uniform, because the beds overlap progressively on the basal formation. However, the maximum thickness must be more than 500 meters. Intrusions of andesite and andesite-agglomerate have pierced the sedimentaries north of the town of Caramoan and again at Palag (or Apatag, as the name is rendered locally) Bay. The strike of the strata varies from north-northeast in the northern and western parts of the sedimentary area to west-northwest farther southeast;

the dips vary in steepness up to the vertical and in direction throughout the southern quadrants. There are at least three limestone horizons in the sedimentary column, but because of the complexity of the geologic structure, their exact position and thickness are undetermined. The succession of beds as indicated by the outcrops is contradictory in different localities, and therefore the presence of faults as well as frequent reversals of dip are suspected.

At the base of the series is a compact limestone, usually red, but also mottled gray at places. This limestone is very pure in some exposures, but elsewhere contains considerable clay and may even grade into calcareous shale. The lower limestone member is lacking in some sections, and conglomerates, clastics, and shale rest unconformably upon a basal formation of peridotitic rocks and fragmental derivatives, thoroughly jointed and metamorphosed.

The shale-sandstone-conglomerate member of the sedimentary column is not uniform in character. Exposures of black calcareous shale in thin, perfectly defined beds were observed in the river north of the town of Caramoan. Sandy yellow to brown shales and massive tuff-sandstone outcrop on the upper part of the same river southwest of Caramoan. It is here, also, that the bed of coal occurs. The horizon is higher than that of the thin-bedded shales to judge by the prevailing southwesterly dip. At Guijalo on the southern coast, and evidently in the base of the series, are fine conglomerates with rounded pebbles of various rocks, including some quartz, shale with calcite lenses between beds, and clastic or fragmental sandstones. The dip is westward, and farther east, on the opposite side of Guijalo Bay, a peridotitic basal complex is exposed, together with blocks of the lower limestone.

A gray, sandy limestone or calcareous sandstone, made up of perfectly defined, thin, hard beds alternating with thicker and softer layers, is included in the upper part of the sedimentary series. The most extensive exposure of this limestone is in the extreme southeastern part of the peninsula, where the beds dip to the south-southwest at angles of from 30° to 40°. The rock has been impregnated with silica, and the thin beds contain numerous concretions of black and gray chert. The intervening softer beds contain a considerable proportion of sharp fragments of tuff. On the surface in this vicinity are numerous pieces of iron-stained quartz, chalcedony, and silicified tuff. Small lenses of tarnished pyrite occur in the softer, thicker beds; these were apparently mistaken for copper minerals during the

Spanish régime. The limestone beds are so crumpled or corrugated at places as to take on an appearance of schistosity (Plate I, fig. 1).

Shale or sandstone, or both shale and sandstone, evidently intervene between the limestone just described and a heavy, upper limestone, to judge from the topography, but my observations were too limited to determine this point with certainty. At the apparent top of the sedimentary series, in any event, there is an extensive limestone member, coralline in origin, but now perfectly massive and partly crystalline. Splendid exposures are encountered in the high ridge trending east-southeastward to Palag Bay. Along the coast in this vicinity the limestone forms magnificent white cliffs, reaching an elevation of 200 meters and rising almost perpendicularly from deep water. On the north coast and also east of the town of Caramoan are hills of the same limestone.

Everywhere this limestone is fissured, and caverns have been formed through solution along the resulting joint planes. In one of the hills near Paniman there is a remarkable limestone cave or underground chamber, which is very aptly designated as "the cathedral" locally. The chamber is circular and has an area of approximately 2,500 square meters. The floor slopes rather steeply from south to north, and at the lower side is a large mass of rock fallen from the roof to precisely the position the altar would occupy in a real cathedral. Appropriately enough, the people of Paniman have surmounted it with a small crucifix. Three openings lead into the chamber, one at the back and one on either side of the altar, forming well-proportioned doors. In the domed roof, fully 30 meters above the highest part of the floor, there is an opening which serves admirably as a skylight. Numerous stalactites, each terminating in a point from which a glistening drop of water is suspended, hang from the arched walls, imparting a suggestion of Gothic architecture to the room.

It is reported that there are several small lakes in the limestone southeast of Paniman near the coast. The water in these lakes is said to be salty and to abound with sea fish. Evidently these lakes must communicate with the sea through subterranean passages.

METAMORPHIC SEDIMENTARY ROCKS

The mass of Caramoan Peninsula consists of metamorphic rocks—talc and mica-schist; schistose, massive rocks; and marble. The schists are evidently of sedimentary origin; indeed the original bedding planes are unmistakable, the planes

of schistosity being parallel to the bedding. The beds are much crumpled and distorted, but nowhere is the original stratification obliterated. I obtained an incomplete section of the metamorphic sedimentaries in the vicinity of Sabang, along a stream which flows into Lagonoy River from the north. The following succession of beds was encountered traveling inland from the coast; since the general strike is west-northwest and the dip is to the south-southwest, the first beds encountered are the youngest and represent the upper part of the series:

TABLE I.—*Geologic section north of Sabang.*

Stratum.	Approximate thickness.
	Meters.
Green schists, imperfectly bedded; compact, hard rocks	200
Fine-grained, homogeneous marble; gray to white	20
Thin fissile beds of talc-schist, schistose shale, and micaceous schists; green, yellow, and brown; quartz lenses along bedding planes	500
White and blue marble	2
Fissile beds of schist like above, but gradually passing into schistose, massive, light green or blue clastic rocks	800
White marble	5
Massive schistose fragmental rocks, light green to blue	(a)

[a] Undetermined.

I was unable to carry this section farther to the north because of the difficulty of penetrating the mountainous country; consequently I did not arrive at the base of the series. In crossing the peninsula from Lagonoy to Sipaco, I passed to the west of the line of the section just recorded and traversed, throughout nearly the entire width of the peninsula, bedded schists with quartz along the bedding planes. However, near the center of the peninsula, the strike of the beds changes from west-northwest to north-northeast, the dip swinging to the west, so that the width of the peninsula is greater than the length of a section across the schist formation. The westward-dipping rocks are less thoroughly metamorphosed than the schists and are clearly thin-bedded shale. On the north coast, also, there is an outcrop of metamorphic rocks, identical in appearance with the thin-bedded shale of the Tertiary sedimentaries, except for the metamorphism. These particular beds retain their original appearance unusually well, because of the fact that they have neither been distorted nor rendered schistose, but have been changed through induration and silicification only. The quartz lenses along the bedding and schistosity planes in the schist

conform to the wrinkling in the beds without any evidence of having been shattered; hence they must have been introduced after the crumpling had been accomplished. Lenses of pyrite are found in the upper part of the green schists much like the lenses of the same mineral in the sandy limestone or calcareous sandstone member of the sedimentary series.

BASAL IGNEOUS COMPLEX

Altered black rocks which appear to be of the subsiliceous igneous type, probably peridotites, are exposed on the southern coast of the peninsula at the base of the sedimentaries. They are closely jointed in several directions and are thoroughly indurated. Hand specimens reveal little except the presence of serpentine. A mantle of closely derived fragmental rock, which is also metamorphosed, obscures the true character and relations of these basal rocks. In the outlying islands north of Caramoan, also, the basal rocks are exposed, and there gneissic diorite is prominent in the igneous complex.

There is a limited area of fresh diorite on the south coast near the point between Guijalo and Parubcan. Likewise there is diorite in the vicinity of Mapid and around Tambang Bay on the north coast. These rocks are holocrystalline, of medium grain, and consist essentially of hornblende and calcic feldspars. At both places the exposures form part of the basal complex into which the diorite is probably intrusive. In the outcrop at Mapid there are a number of veinlets containing chalcopyrite and pyrite, together with quartz and some calcite.

Along the eastern coast of the region northwest of Tambang Bay there is a continuous exposure of a black, igneous-appearing rock which, from its general appearance, I believe to be peridotic in character. Both my trips along this coast were made in rough weather in a small boat; consequently I had little chance to examine the outcrops. Specimens which I secured were lost subsequently when my boat capsized. If the rock is peridotite, it is undoubtedly to be correlated with the peridotite farther west in the Paracale mining district, and the Paracale peridotite is probably the equivalent of the metamorphosed peridotic rocks in the basal complex upon which the Caramoan sedimentaries were deposited. Upon this basis the region northwest of Tambang Bay is mapped as part of the basal igneous complex. It may be, however, that the rock in question is a massive flow related to the tuff-agglomerate-flow series. Certainly it has less appearance of metamorphism than the average basal-complex outcrop.

On the western end of the peninsula, bordering San Miguel Bay, there is an area of light-colored schistose porphyry, which was identified as schistose andesite by Smith.[6] This rock is grouped with the basal igneous complex in this preliminary study, but there is no certainty that it is as old as the basal rocks.

CORRELATION

Mount Isarog is one of the older of the extinct volcanoes in the Philippines. Mount Mariveles, near Manila, is usually taken as the type of these older volcanoes, the lavas of which were more siliceous than the ejecta from the subsequently active volcanic centers. The activity of Mount Mariveles, according to Smith,[7] began in Pliocene time and continued into the Pleistocene; a corresponding age may be assigned to the Isarog ejecta.

The tuffs, flows, and agglomerates on the northern coast appear to be in some degree contemporaneous with the upper part of the Tertiary sedimentaries, assuming that the tuff observed in the limestone beds near the top of that series is related in origin to the tuff of the volcanic formation. In Cebu there are tuffs and flows immediately beneath the limestone, which Abella[8] fixed as Post-Pliocene. Tuffs, flows, and agglomerates similar in appearance to those in Caramoan and probably of corresponding age are found in the Laguna de Bay region east of Manila. Without much question these various occurrences may be correlated and placed in the Pliocene or upper Miocene.

The upper part of the sedimentary series corresponds roughly with the limestone, sandy limestone, and clay-tuff at the top of the sedimentary rocks in the petroleum fields of Tayabas and Leyte.[9] The work in Tayabas fixed this general horizon as upper Miocene and Pliocene. The shales and associated rocks in the lower part of the sedimentaries may be correlated directly with similar rocks elsewhere. The coal horizon and the underlying thin-bedded shale are recognized characteristics of the Philippine Tertiary. In the basal limestone of the Cebu series I found fossils which Smith[10] identified as *Heterostegina margarita*

[6] Dr. Warren D. Smith made a petrographic study of the rocks collected during the field work for the reconnaissance of southeastern Luzon, which included this rock.

[7] *This Journal, Sec. A* (1913), 8, 235 et seq.

[8] Abella y Casariego, Enrique. La Isla de Cebu. Imprenta y Fundición de Manuel Tello, Madrid (1886), 120.

[9] *This Journal, Sec. A* (1913), 8, 301 et seq. Ibid. (1915), 10, 241.

[10] Ibid. (1914), 9, 157.

Schlumberger (Oligocene?). Therefore the sedimentaries are not older than the Oligocene.

The metamorphic sedimentaries exhibit a succession of beds identical in its main features with the Philippine column of Tertiary sedimentaries. The observed sections in the metamorphosed sedimentaries and in the unchanged sedimentaries farther east are similar, although the lower part of the metamorphosed section is developed in greater thickness than the corresponding division of the unchanged rocks. Moreover, in ascending Caramoan River, one passes gradually from unchanged sedimentaries to metamorphosed sedimentaries: that is to say, there is an evident transition from one formation to the other with no definite line of contact.

In short, the schists and marbles appear to be no older than the shales and limestones. Indeed these rocks appear to be different sections of continuous beds which have been metamorphosed in their westward extension but have escaped metamorphism farther east.

Thus the schists and marbles are likewise not older than the Oligocene, and the antiquity which has been ascribed to the metamorphic rocks generally in the Philippines is opened to question. Paleozoic schists are found in Japan and in Formosa, and they may exist in the Philippines, but the extensive area of more or less typical schists on Caramoan Peninsula belongs to a later period.

The basal igneous complex upon which the Tertiary beds were laid down obviously antedates these beds, but its age cannot be more definitely fixed. The age of the schistose andesites, grouped for convenience with the basal igneous complex, is likewise undetermined.

GEOLOGIC HISTORY

The geologic history of Caramoan Peninsula, so far as it may be deduced from the data in hand, begins with an eroded pre-Oligocene basal formation, principally a complex of igneous rocks. From Oligocene time through to the Pliocene this basal formation was submerged, and sedimentary rocks were laid down over it. Whether each division of the sedimentaries is strictly conformable over the preceding deposits is not certain, but no unconformities were observed. The metamorphic andesite in the western part of Caramoan was introduced, presumably as a flow, during or preceding the deposition of the sedimentary rocks.

Dynamism, severe enough to change the sediments into true

schists, succeeded the period of sedimentation. This dynamism affected most strongly the central and western parts of the peninsula and left the sedimentaries at the eastern end unmetamorphosed. The rocks converted into schist have not lost their original bedded structure. The igneous basement upon which the sediments lie has not been rendered thoroughly schistose, but this is probably because the igneous rocks were less responsive to dynamic action than the bedded rocks. Just what form the dynamism assumed is undetermined. Adams[11] concluded that Caramoan Peninsula had suffered a severe thrust from the Pacific (northern) side and perhaps this is the true explanation. Certainly the strata have been forced into folds along a predominatingly west-northwest line, and over comparatively extensive areas the sedimentary and metamorphic rocks are inclined at steep angles southward.

Subsequent to the period of metamorphism quartz was introduced along bedding planes and fractures, forming quartz lenses in the schists and concretions of chert locally in the unmetamorphosed limestones. Perhaps the observed pyrite lenses and the veinlets of pyrite and chalcopyrite are related to this activity also. The volcanism which produced the tuffs, flows, and agglomerates of andesite along the northern coast began toward the end of the period of sedimentation, but belongs essentially to a later time. Finally came the extrusion, which built up Mount Isarog and joined Caramoan to the mainland of southeastern Luzon.

During recent times erosion and the submergence evidenced by the drowned appearance of the north coast have been the principal factors in modifying the contour of Caramoan Peninsula. The recent submergence has permitted the Pacific to advance on the land, drowning the rivers and submerging, except for the highest points which remain as islands, a considerable area that formerly extended to the north from Caramoan Peninsula. At present the submergence is no longer in progress, but to judge from slightly raised beaches along the north coast, elevation has once more begun.

ECONOMIC GEOLOGY

GENERAL

Caramoan Peninsula is important principally on account of its forest resources. Neither agriculture nor mineral industries have become prominent on the peninsula proper, although hemp

[11] *This Journal, Sec. A* (1911), 6, 469.

and sugar planting are remunerative in the vicinity of Mount Isarog.

The alluvial and littoral deposits support the larger part of the population. These formations and the Isarog tuff and agglomerate yield rich soils and lend themselves to agricultural development. The volcanics on the north coast, on the contrary, appear to support little vegetation. No attempt has been made to cultivate this part of the peninsula, but in place of the heavy forests which abound in some other parts of the area the natural vegetation on the tuffs and flows consists principally of hardy cogon grass. There is no evidence that this region ever was forested. The sedimentary rocks are also comparatively barren of vegetation. However, the original forest has been cut away over the sedimentaries, permitting the cogon grass to replace it. Except for the crystalline limestone this formation should disintegrate rapidly enough and form a fairly good soil. The metamorphic rocks appear to yield good soils in spite of their induration; at any rate, they support a splendid forest growth. The Caramoan forest concession, which is considered to be particularly valuable, covers principally metamorphic rocks and the Isarog tuff-agglomerate formation. The unaltered igneous rocks, again, are comparatively barren; cogon grass and a small evergreen tree, said to be a variety of "iron wood," mark the igneous exposures.

GOLD

The quartz lenses in the schists carry a trace of gold; so, also, do the pyrite lenses. But there is no evidence of valuable gold deposits on Caramoan Peninsula. Becker[12] was led to the conclusion that "in all cases in the Philippines of which the details are known, crystalline schists accompany gold-quartz veins, copper ores, iron ores, and galena." If this condition really existed, it might be assumed, conversely, that an area of crystalline schists would be likely territory for the gold prospector, but the case of Caramoan Peninsula does not bear out this conclusion. As a matter of fact, subsequent work has shown that some of the more important gold deposits in the Philippines are not related to the crystalline schists. Moreover Becker believed most of the Philippine crystalline schists to be of comparatively great age and had in mind such older crystalline schists. Therefore the Caramoan schists, being geologically young rocks, would not be expected by Becker to contain gold.

[12] Becker, George F., *21st Annual Rept. U. S. Geol. Surv.* (1901), 237, reprint.

COPPER

Enrique D'Almonte's map of Luzon (1883) indicates copper at two places near the eastern end of Caramoan Peninsula. Jagor [13] states that he saw metallic copper which came from a place north of Patag (Palag) Bay, in the vicinity, apparently, of the mines indicated by D'Almonte. The people of Lagonoy remember a Frenchman who mined for copper north of that town about thirty years ago. Becker quotes Roth to the effect that Caramoan Peninsula is probably composed of crystalline schists, judging by the reported occurrence of copper there.

I found no copper at the points indicated by D'Almonte, although I was conducted to the supposed mines twice, each time by a different guide. But I did find on each occasion the tarnished pyrite lenses to which I have already referred. These are found not in schists in eastern Caramoan, but in calcareous sandstone. They are apparently the only basis for the reported copper discoveries. Jagor would not have mistaken this mineral for copper, but it is very doubtful if the copper shown to him came from Caramoan Peninsula. At the place north of Lagonoy, where the Frenchman is supposed to have worked, similar pyrite lenses abound, and in this case they really occur in schist, as Roth supposed of the copper, but no copper minerals accompany them.

The only copper I saw on Caramoan Peninsula occurs as the mineral chalcopyrite in veinlets in diorite near the barrio of Mapid. The deposit at this place is of no economic importance.

MERCURY

The presence of metallic mercury on Mount Isarog has repeatedly been affirmed by the people near that mountain and has been reported to both the Spanish and American mining offices. The reports are persistent, and it is beyond question that the primitive people (Negritos) living on the upper slopes of Mount Isarog are acquainted with the physical properties of mercury. I found that they could describe it accurately, even though they considered it to be a valuable medicinal charm. But I was unable to find any mercury or even cinnabar myself. My guide, a Negrito, assured me that it was very scarce, and recommended that I would do better to come again at a more favorable time. All Saints Day, he thought, would be best, and then if I were very lucky and followed a certain stream from mouth to source, I might find a little mercury which would shine, he said, from

[13] Jagor, F., Reisen in den Philippinen. Wiedmann'sche Buchhandlung, Berlin (1873), 145.

the bottom of some pool. Solfatarism is common on Isarog, and the presence of mercury in the vicinities of some of the solfataras is not impossible.

COAL

There is an outcrop of coal in the sedimentary rocks along Caramoan River about 2 kilometers upstream from the Guijalo-Caramoan road. The outcrop has been known for at least seventy years. The bed is about 50 centimeters thick, and the coal is a dirty black lignite. The strike is nearly north, and the dip is westward at a high angle. Isidro Sainz de Baranda, the first inspector of mines under the Spanish régime, and a capable man, believed the coal from this outcrop to be of good quality. No tests have been made of it, but its appearance is not promising, and the outcrop indicates too thin a bed to be commercially important. Several concessions for this coal were sought in Spanish times, and in 1898 a concession was finally granted, but title was never perfected under the American laws. The vicinity of Guijalo was formerly known as Puerto de Minas in anticipation of its importance as a shipping point for this coal.

I was informed that coal had been found in the hills near the barrio of Parubcan and was shown a specimen of good coal which was alleged to represent the outcrop. I was unable to find the coal in place, however, even with the assistance of several guides. If the beds of schist at Parubcan inclose coal, it should be a coal of good quality because of the metamorphism it must have undergone.

CLAY

The light-colored talc-schists in the vicinity of Lagonoy are used as paint clay in the neighboring towns. The paint is grayish white and adheres tenaciously to wood. A good white clay is obtained at a place called Sulpa on Looc River, between Tinambac and Siruma, in the northeastern part of the peninsula. This clay appears to result from the decomposition of quartz-feldspar rocks which occur as dikes in the schistose andesite. The clay is plastic, although in the crude state it contains fragments of quartz, and should make a fair grade of pottery or refractory ware.

STONE AND GRAVEL

Possibly some of the marbles and limestone on Caramoan Peninsula could be exploited for construction purposes. The marble in the vicinity of Sabang is most conveniently located, and if there were a demand for it, could be quarried advantageously.

A heavy, dense, dark-colored schist from northwest of Lago-

noy is used by the Filipinos to manufacture whetstones for sharpening bolos. The stone appears to serve this purpose very well, but the demand for whetstones is not great enough to make the manufacture steady or profitable.

At several places along the southern coast, between Sabang and Parubcan, there are extensive beaches of perfectly rounded gravel of sizes suitable for use without reduction in road building. The pebbles are of hard metamorphic rocks, and while they tend to assume flat rather than spherical forms, they should make a superior road metal.

ARTESIAN WATER

Only a few wells have been drilled on Caramoan Peninsula, but the drilling campaign which the Bureau of Public Works is carrying on will ultimately extend to this region, and the possibilities of obtaining artesian water should be considered.

The metamorphic and igneous rocks on Caramoan Peninsula will probably be found to be comparatively dry. If no water is obtained from the first or second test-well in these formations, no more wells should be drilled into them. The tertiary sedimentaries have been shown by experience elsewhere to be usually barren of artesian water. Therefore they will probably also be dry in Caramoan Peninsula. The volcanic tuffs and flows on the north coast may possibly yield artesian water, but they offer little promise; in general, they are too close-grained to yield strong flows.

There remain the alluvial deposits and the Isarog tuffs and agglomerates. Both these formations are undoubtedly water-bearing and with proper care should be made to yield potable water from comparatively shallow wells. The Isarog formation may contain mineralized water at places and may require deeper wells than the alluvium. The alluvium on which Caramoan lies should receive attention when wells are drilled for that town. It should be saturated above the sedimentary floor on which it rests, and a series of shallow wells should meet the requirements of this town. If they do not, there is little hope of obtaining water, because the underlying sedimentaries are almost certainly not water-bearing. Likewise the areas of alluvium overlying the metamorphic rocks should be tested in advance of the metamorphics themselves.

The prospects for artesian water are fairly good, then, at the towns of Caramoan, San Jose, Sabang, Lagonoy, Goa, and Tinambac; but elsewhere, except within alluvial areas or the Isarog volcanic formation, artesian water will probably not be obtained.

ILLUSTRATIONS

(Photographs by Pratt.)

PLATE I

TEXT FIGURES

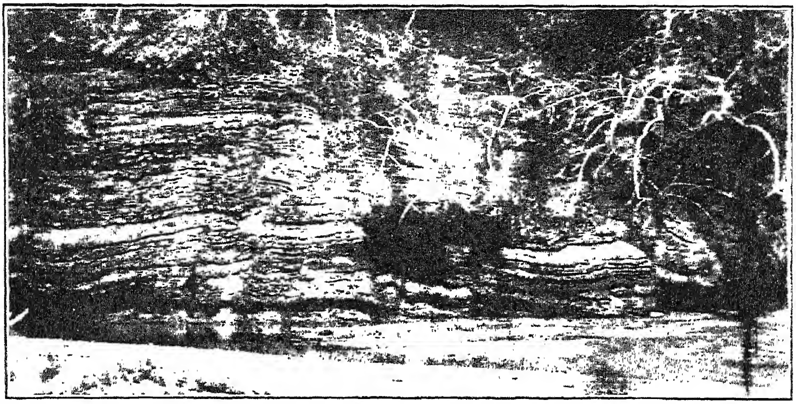


Fig. 1. Crumpled thin-bedded limestone near Palag Bay.

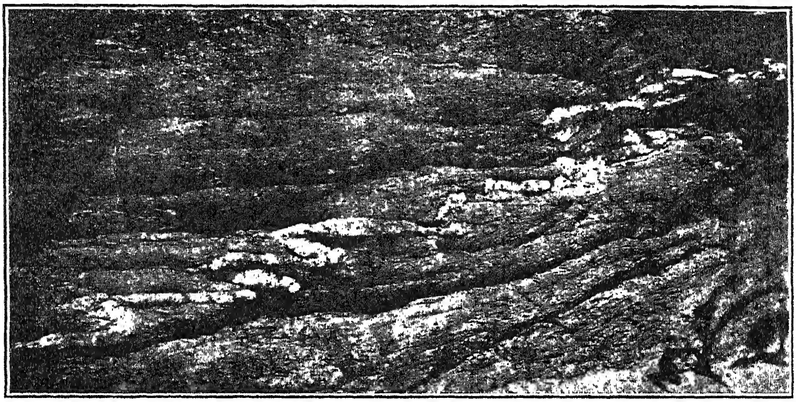


Fig. 2. Sinuous quartz vein in schist near Sabang.

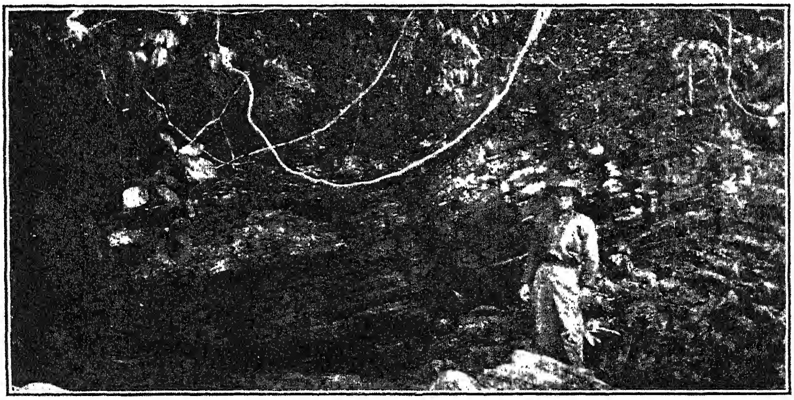


Fig. 3. Weathered outcrop of marble in schist near Sabang.

PLATE I.

IRON ORE ON CALAMBAYANGA ISLAND, MAMBULAO, CAMARINES [1]

By WALLACE E. PRATT

(From the Division of Mines, Bureau of Science, Manila, P. I.)

TWO TEXT FIGURES

SITUATION

The Calambayanga iron-ore deposit is situated on the western part of Calambayanga Island and on the adjacent mainland over an undetermined distance. Calambayanga is the name by which the Coast and Geodetic Survey designates a small island in Mambulao Bay on the north coast of Camarines Province, southeastern Luzon (fig. 1). The name is more commonly rendered

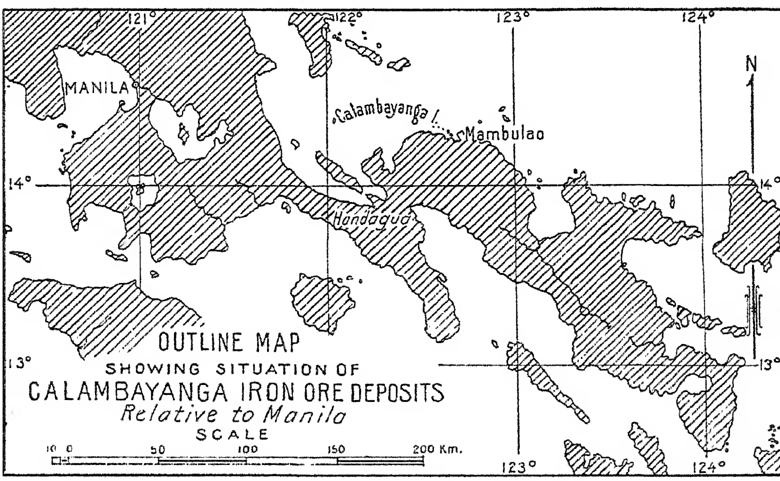


FIG. 1. Showing situation of Calambayanga Island, Camarines Province.

Calambayunga by the local inhabitants. Mambulao Bay is 185 kilometers (115 miles) in a straight line directly east of Manila. The usual sailing route for steamers encircles southeastern Luzon and is about 900 kilometers (560 miles) long. By combined railroad and steamship routes the distance is not much longer than a straight line from Manila to Mambulao.

Calambayanga Island is a little more than 1,100 meters (0.7 mile) in length with a maximum width somewhat greater

[1] Received for publication April 23, 1915.

than half its length. It is elongated in a north-south direction, and attains an elevation of 70 meters (230 feet). The island is separated from the mainland to the south of it by a stretch of shallow water about 500 meters (1,600 feet) wide. Text figure

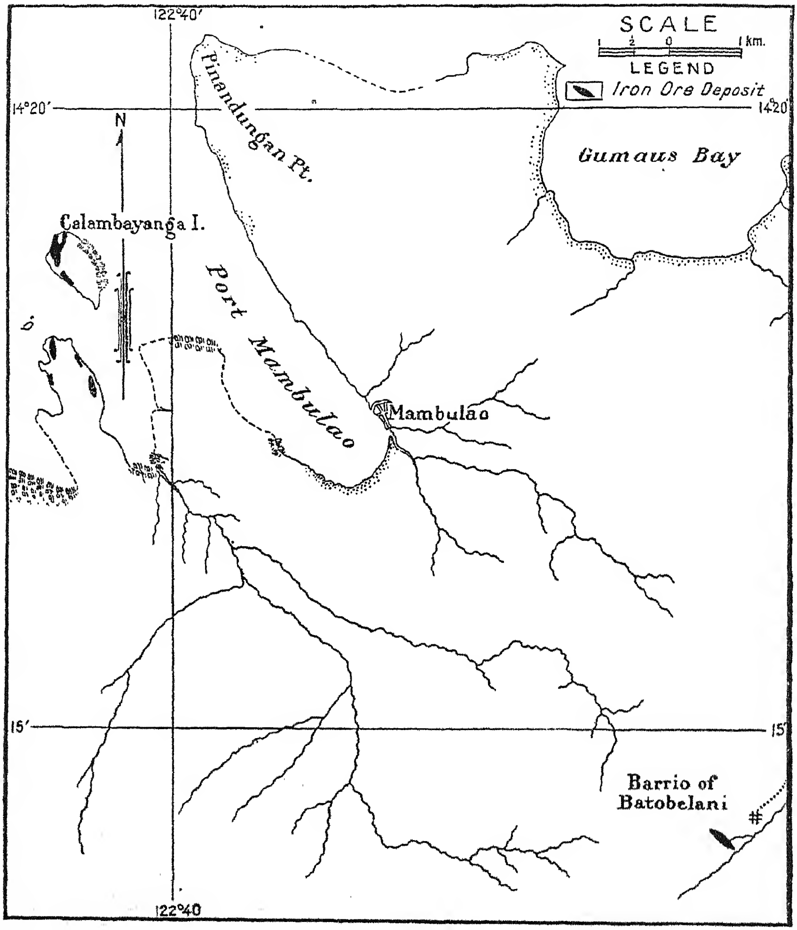


FIG. 2. Showing the location of the Calambayanga iron-ore deposits, Camarines Province.

2 shows the general situation of Calambayanga Island. Off the northwest point of the island the sea has a depth of 10 meters (33 feet) within 100 meters of the shore line, and a depth of 7 meters (23 feet) persists to within 50 meters of the western shore line. By utilizing small outlying reefs to the

north, in the construction of a short breakwater, it would be possible to make a small secure harbor at this point with no great expenditure. Dahikan Bay, 4 kilometers (2.5 miles) to the east of Calambayanga Island, is charted as a safe anchorage by the Coast and Geodetic Survey.

Fresh water is to be had only in limited quantity on the island itself, but could be obtained in abundance on the adjacent mainland. There are several small springs on the island, and in the rainy season these give rise to a small stream.

HISTORY

Concessions for iron mines on Calambayanga Island were sought repeatedly during the Spanish control of the Philippine Islands, but there is no record that any was granted. The iron ores in the Eastern Cordillera of Luzon were known and exploited in the seventeenth century, and probably the deposit on Calambayanga Island was discovered at a similarly early date. It is probable that Filipino iron smelters were operated at the Calambayanga deposit, as they have been in Bulacan Province, since pieces of slag and inclosed charcoal much like the Bulacan slags have been found near Mambulao by Mr. A. C. Cavender, the present owner of the Calambayanga ores.

GENERAL GEOLOGY

The Calambayanga iron ore lies at the western border of the Paracale gold field, which has been productive for three centuries and at present yields nearly 50 per cent of the total gold production of the Philippines. The gold appears to be associated with granite, which is intruded into more basic rocks—diorite and peridotite; the gold is found in veins which formed in the granite and the surrounding rocks after the solidification of the intrusion. To the west and southwest of and overlying the granite and diorite area is a series of sedimentary rocks younger than the granite and probably of Miocene age. The iron ore is found in the base of these sedimentaries, which include sandstones, conglomerates, shales, tuffs, and minor limestones. All the rocks in the district have been metamorphosed by regional dynamic action, and the sedimentary rocks have been pierced by dikes and overspread by flows and agglomerates. Probably the dynamism which rendered the granite gneissic and the diorite schistose over the whole district and indurated, folded, and faulted the sedimentary beds was accompanied or followed by the extrusions, which are andesite. The fractures

which were formed in the granite during metamorphism were filled by gold-bearing quartz. One of the products of the mineralization associated with the intrusion of the dike rocks into the sedimentaries is the iron ore in question.

CHARACTER OF THE IRON-ORE DEPOSITS

The ore body on Calambayanga Island appears to be irregular in shape, but to conform more or less closely to the strike and dip of the sedimentary beds in which it occurs. It outcrops on the western part of the island and is roughly oval or lens-shaped in plan. Ore of exactly the same character is encountered on the mainland to the south, where exposures are seen at intervals for a distance of at least 2 kilometers (1.2 miles) inland. A small island south-southwest of Calambayanga Island and considerably to the west of a line between it and the outcrops on the mainland is composed wholly of iron ore of the same character. Again, at Bato-bolani, 12 kilometers (7.5 miles) southeast of Calambayanga Island and still near the line of contact between the sedimentaries and the older igneous rocks, iron ore similar in character to the Calambayanga ore is found.

At each of these places the outcrops are marked by great blocks of black ore, angular in form and with pitted, irregular surfaces. These blocks have been designated as bowlders by several observers, but the term bowlder conveys a wrong impression, inasmuch as the masses of ore at the outcrops show no evidence of having been transported, but have the appearance of disintegration products in place. They vary in size up to masses of many tons' weight. At the prominent outcrops they occur to the exclusion of all other rocks, but elsewhere they are isolated from each other and are embedded in yellow, residual clay.

Only the Calambayanga ore body has been examined closely by me. The western half of the island is strewn with blocks of ore. The northeastern part is made up of sedimentary rocks, principally sandstones, or fine-grained clastics, shales, and conglomerates. At the northern extremity of the island the beds strike north 20° east and dip 45° to the west, but toward the south, along the east coast, the strike changes gradually until it is north 60° west with the dip to the south. A bed of crystalline limestone outcrops in the sedimentaries halfway along the eastern coast, and some of the other sedimentary beds are calcareous. Minor outcrops of stratified rocks are found on the eastern coast, but here the strike is north 60° west, and tuffs, agglomerates,

and fragmental rocks predominate over other types. These volcanic rocks are less indurated than the sedimentaries on the eastern shore of the island, and there is a consequent suggestion that they belong to a separate younger formation.

Extending north-northwest into the mass of the island from the southeastern point is a great outstanding body of quartz, a lode or vein, with a width of possibly 100 meters. This quartz is mineralized and contains numerous veinlets of iron ore. A shallow pit has been sunk in the quartz near the center of the island, and a sample taken from the wall of this pit showed upon assay a trace of gold. The sedimentary rocks to the east are highly silicified near the contact with the quartz.

The outcrop of the quartz becomes concealed toward the north-northwest by a mantle of clay, but on the northwest shore, approximately at the point where the quartz should reappear, if it continued so far, there is encountered a dike of dark-colored gabbro between agglomeratic tuff and sedimentaries. This dike is vertical and strikes north 60° west. A small vein of quartz carrying unaltered fresh pyrite was observed in it. Under the microscope the dike rock is seen to be holocrystalline and to consist principally of plagioclase feldspar and pyroxene. The feldspar predominates and occurs in large lath-shaped crystals with a parallel arrangement. The pyroxene appears to be much decomposed, and associated with it throughout the section is magnetite in considerable abundance.

Along the western and northern shore line of the island the blocks of iron ore are present in great abundance and lie one upon another with no intervening foreign material. Farther up the slopes, however, and at the summit of the island the blocks are scattered over the surface, embedded in residual clay.

Fanning [2] studied the ore on the mainland; he traced the outcrop of the ore for a total distance of 3 kilometers (including the outcrop on the island?). The width as revealed to him by occasional outcrops in place varied up to 15 meters. Sedimentary rocks are found on the mainland, as on the island, and similarly are indurated, tilted at various angles, and pierced by dikes. Volcanic tuffs, agglomerates, and flows are prominent on the mainland and on the neighboring small islands.

At Bato-bolani the iron ore occurs in large blocks scattered over the side of a hill. The ore is magnetite with some hematite and carries also fresh quartz and pyrite. F. Rinne,[3] a German

[2] Smith, W. D., and Fanning, P. R., *Min. Res. P. I. 1910* (1911), 58.
[3] *Zeitschr. f. prak. Geol.* (1902), 10, 117.

geologist has published a description of the Bato-bolani ore deposit from which the following extract is quoted:

It might be thought that the magnetite masses here are a segregation from an igneous rock, probably from the diorite found between the masses of ore. It is surprising, however, in explaining the magnetite as a magmatic segregation that nowhere was the contact between the diorite and the ore to be seen. The ore masses were encountered everywhere without any adhering or inclosed pieces of diorite. This circumstance indicates strongly that the once existing rock with which the present blocks were associated was comparatively easily destroyed, so that the ore, freed through weathering, is now nowhere in continuity with it. In this connection the occurrence of a dark-colored limestone, of which several pieces were found at a place on the same slope, is interesting. It is possible that the ore masses were enveloped in this easily soluble limestone. It appears to me very plausible that the magnetite blocks at Bato-bolani were formed by contact phenomena between diorite and the limestone, which is still found in traces over the former surface of the igneous rocks. * * * One could suppose that the ore formed in the limestone under the influence of the solutions and gases coming from the cooling diorite magma. I did not observe other contact minerals such as garnet, at the place, but in complete accordance with this theory is the occurrence of nests of yellowish white, needlelike quartz which are found sparingly in the magnetite. In places the ore particles build a sort of frame or skeleton, the spaces of which are filled with quartz.

CHARACTER OF THE ORE

The iron ore on Calambayanga Island and on the adjacent mainland is almost pure hematite with only traces of magnetite. The hematite is massive or granular, and the ore is moderately soft and very porous, or vesicular. At places over the exposure a small proportion of pyrite in fresh crystals may be detected in the hematite, and likewise quartz is found sparingly in scattered grains or in veinlets. Copper stains were found in the slightly pyritiferous ore at two places, indicating that some chalcopyrite occurs with the pyrite.

The Bato-bolani ore contains much more magnetite than the ore on Calambayanga Island; it is also harder and shows more pyrite and quartz, but otherwise the ores are similar.

The composition of the ore is shown in Table I. Analysis 1 is to be given greater weight than any of the others because of the larger quantity of ore which it represents. Apparently the average ore carries about 60 per cent of iron and is reasonably free from objectionable constituents. In only one analysis is the phosphorus above the Bessemer limit.

GENESIS OF ORE DEPOSIT

The observations set forth in this report have led to the conclusion that the ore on Calambayanga Island is related in origin

TABLE I.—*Analyses of iron ores from Calambayanga Island.*

[Figures give per cent.]

Constituent.	Sample.					
	1	2	3	4	5	6
Silica (SiO_2)	1.02	1.29				8.71
Alumina (Al_2O_3)	1.31	6.52				
Ferric oxide (Fe_2O_3)	97.35	68.28				
Ferrous oxide (FeO)		9.22				
Lime (CaO)		2.77				
Magnesia (MgO)		0.29				
Manganese (MnO_2)	0.11	0.09				
Phosphorus (P)	0.001	0.10	0.001	0.005	0.008	0.035
Sulphur (S)		0.12	0.138	0.07	0.067	trace
Total iron (Fe)	64.14	54.96	57.11	63.69	46.06	65.76

1. Calambayanga ore: Average composition of a sample of 200 kilograms (440 pounds) of representative ore from Calambayanga Island. Analysis by T. Dar Juan, chemist, Bureau of Science.

2. Calambayanga ore: Hand specimen; analysis by Forrest B. Beyer, formerly chemist, Bureau of Science.

3. Calambayanga ore: Sample taken by P. R. Fanning, formerly assistant, division of mines, Bureau of Science, representative of many blocks of ore along entire outcrop on Calambayanga Island. Analysis by T. Dar Juan, chemist, Bureau of Science.

4. Calambayanga ore: Sample taken by P. R. Fanning, formerly assistant, division of mines, Bureau of Science, from many blocks of ore over a distance of 500 meters on mainland near Calambayanga Island. Analysis by T. Dar Juan, chemist, Bureau of Science.

5. Calambayanga ore: Sample taken by P. R. Fanning, formerly assistant, division of mines, Bureau of Science, on Calambayanga Island from a single lump specimen. Analysis by T. Dar Juan, chemist, Bureau of Science.

6. Bato-bolani ore: Hand specimen taken by H. M. Ickis, formerly assistant, division of mines, Bureau of Science; analysis by H. S. Walker, formerly chemist, Bureau of Science.

to the quartz vein or lode with which it is associated. Veinlets of ore are found in the quartz, and quartz occurs sparingly in the ore. The processes which produced the body of quartz probably yielded under different local conditions the adjacent body of iron ore. Both types of mineralization probably resulted directly or indirectly from the intrusion of dikes into the sedimentary rocks near the contact with the older igneous base. Apparently there was some replacement of the wall rocks as well as the filling of cavities and fractures. Probably the limestone and the calcareous sediments were most susceptible of replacement in this manner. The dike of gabbro on the northwestern shore of the island with its notable proportion of magnetite may be taken to represent a part of the intrusive rocks. The tuff and agglomerate on the shore of the island and on the neighboring islands and mainland are surface extrusions which may be related genetically to the dike rocks.

Rinne concluded that the Bato-bolani ore had resulted from

contact mineralization, probably at the contact of intrusive diorite and limestone. The Bato-bolani and Calambayanga ore deposits prove upon examination to be very much alike, except that magnetite is the predominant ore mineral at Bato-bolani, whereas hematite predominates at Calambayanga. Probably the two deposits are related in origin, and certainly the observations recorded herewith on the Calambayanga deposit are evidence of a genesis similar to that suggested by Rinne for the ore at Bato-bolani.

Certain general characteristics are common to the iron ore at Calambayanga, at Bato-bolani, and in Bulacan Province:[4] for example, the association of the ore with intrusive rocks in sedimentaries, especially limestones; the nature of the ore minerals; and the presence of quartz in the ore. In some of the Bulacan deposits the replacement of limestone by ore is clearly evident.

QUANTITY OF ORE AVAILABLE

No development work which throws any light on the dimensions of the deposit nor the persistence of the ore with depth has been done on the Calambayanga ore. The only direct evidence which can be brought to bear in a discussion of quantity is the extent of the outcrops. But even the dimensions of the outcrop cannot be determined accurately because of the fact that the ore is encountered only in blocks which afford no precise data as to the width of the ore in place. The size and abundance of these blocks and the length of the line along which they occur have led several observers to the conclusion that they represent an ore body, or ore bodies, of great size. Fanning,[5] for instance, concluded:

> The quantity of hematite cannot be estimated at the present time because experience in other fields where enormous quantities were indicated on the surface shows that they may not be realized at depth. Whether or not this will be true for this formation is a matter for future development to determine. * * * The surface indications are excellent, yet the amount and quality of the ore are unknown. It is unquestionable, however, that the property is worthy of extensive development.

Adams, also, examined the Calambayanga deposit and commented on it as follows:[6]

> A deposit of iron ore in the form of a dike cutting sedimentaries is found on a small island in Mambulao Bay. It continues on the mainland

[4] Dalburg, F. A., and Pratt, Wallace E., *This Journal, Sec. A* (1914), **9**, 201.

[5] See footnote 2.

[6] *This Journal, Sec. A* (1911), **6**, 463.

where there are conspicuous outcrops. The strike is about north 5° west. This ore body has a width of as much as 13 meters at several places. Smaller outcrops occur near by. The ore is high grade hematite and is a workable deposit containing an immense tonnage.

Rinne, previously quoted, found that the blocks of ore at Bato-bolani were distributed over an area 200 meters (650 feet) wide by 400 meters (1,300 feet) long. He questioned the popular belief that the whole mountain was iron ore, however.

The area on Calambayanga Island over which blocks of iron ore are distributed is roughly 500 meters (1,650 feet) long and 200 meters (650 feet) wide, and blocks of the largest size are found all the way from sea level up to an elevation of 70 meters. There is every evidence that these great masses of ore have not been transported far; they must be practically in place. But from the nature of the ore deposit, it is obviously not safe to assume that beneath the surface there is a solid body of ore with dimensions equal to that of the area over which the surface blocks are scattered. The shape of the ore body may be very irregular, and without more data than is at present available no definite estimate of the quantity of ore can be made. If the ore deposit originated as suggested in this paper, the ore should persist with depth—that is, it should not be confined to the present surface. However, its vertical dimensions, like its horizontal dimensions, are probably irregular and cannot be estimated.

The ore on the island appears to be sufficient in quantity to be commercially important. It is probable that there is even a greater quantity of ore on the adjacent mainland, and the smaller island of ore to the west of a line from Calambayanga Island to the ore on the mainland is evidence of even wider ramifications of the mineralization. The ore in sight is undoubtedly to be estimated in hundreds of thousands of tons, but the total quantity of ore available is undetermined. It is impossible to escape the conviction, however, that the surface indications warrant capital in making the exploration requisite to determine the extent of the ore body. Preliminary exploration could probably be accomplished best by diamond drilling, and the expense of drilling at this site should be close to the minimum for this class of exploration.

ILLUSTRATIONS

TEXT FIGURES

IRON ORE IN SURIGAO PROVINCE [1]

By WALLACE E. PRATT and VICTOR E. LEDNICKY
(*From the Division of Mines, Bureau of Science, Manila, P. I.*)

ONE PLATE AND 1 TEXT FIGURE

CONTENTS

INTRODUCTION

Between the towns of Gigaquit and Cantilan on the eastern coast of Surigao Province, Mindanao, the country is conspicuously barren of vegetation, and the hills are covered with a mantle of red soil. The barrenness of these hills, so strongly in contrast with the heavy forests commonly observed in uninhabited country, has often attracted attention and comment. The Coast and Geodetic Survey charts of this coast, for instance, bear the notation "Red Hills" across the central part of the barren region.

Mr. H. F. Cameron, chief engineer for the Department of Mindanao and Sulu, first recognized the true character of the red earth which makes this section of the coast so conspicuous. Mr. Cameron was struck with the similarity between the Surigao red earth and the clayey iron ores of the Nipe Bay region in Cuba. He procured samples, which were analyzed by official request in the Bureau of Science, and were proved to be in reality high-grade iron ore. Mr. Cameron believed his samples to be representative and that the deposit of iron ore was enormously large. Following this report, which was made officially, the area covered by the ore was reserved by executive order from mineral location, pending a further examination to determine the character of the ore and the extent of the deposit. This paper contains the results of the official examination which was made during the latter part of February and the first part of March, 1915.

[1] Received for publication June 29, 1915.

GEOGRAPHY

SITUATION

The reservation which was made to cover the Surigao iron ores includes all territory lying east of a north-south line through the town of Gigaquit and north of an east-west line through the town of Cantilan. These lines, together with the sea coast, define a triangular area in the eastern part of northern Surigao. Gigaquit, the northern point of the reservation, is about three hours' journey by small coasting steamer southeast of Surigao,

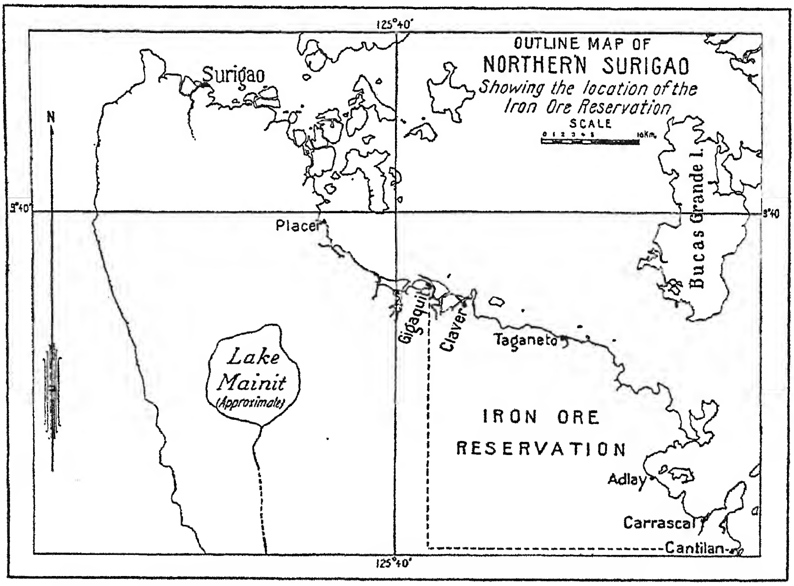


FIG. 1. Outline of northern Surigao, showing situation of iron-ore deposit.

the provincial capital and port of call for boats from Manila (see Plate I and fig. 1). The territory actually covered by the iron-ore formation is considerably smaller than the reservation, but occupies a strip along the coast within the boundary lines. The sea off the eastern coast of Mindanao is exceedingly rough during six months of the year, and good harbors are scarce. Practically the only natural harbor in the iron-ore region is Dahikan Bay. The waters inside this bay are thoroughly protected at all times and are abundantly deep (18 to 28 fathoms). However, the entrance to the bay is narrow and might be difficult of passage in rough weather.

PHYSIOGRAPHY

The iron-ore deposit covers a region which attains only moderate elevations, but is of sharp relief. Mount Legaspi, elevation 1,170 meters, is the highest point included within the boundaries of the iron-covered territory. Other peaks near the western edge of the deposit are as high as from 500 to 700 meters. The region slopes from Mount Legaspi eastward and northward to the coast, but the slope is by no means regular or continuous. The country is deeply incised; even the smaller streams flow through deep and precipitous valleys. This is a result of the exceedingly heavy rainfall between the months of October and March. The weather-recording station at the town of Surigao shows an average annual rainfall of over 3,000 millimeters, most of which occurs during the above-stated months. The hills rise abruptly from the coast, and much of the coast line is marked by sea cliffs. The outline of the coast is fairly regular, but is broken by several prominent points and bays.

Only two rivers of any size flow across the iron-ore deposits. One of them, flowing north, discharges its waters into the sea at the barrio of Taganito; the other drains the eastern flank of Mount Legaspi and flows to the south, reaching the sea at Carrascal. Either of these rivers could probably be made to yield a fair amount of water power, but no data are available on their volumes.

VEGETATION

One of the most remarkable features of the ore deposit is the unusual character of the vegetation covering it. Near the coast and over most of the area of the deposit the ground is largely bare, with scattered clumps of brush or shrubs and occasional patches of weedlike ferns. Everywhere, however, there is evidence of a former forest growth in the decaying trunks of fallen or even standing trees. These dead trees were as large on the average as those one finds growing in the normal forests at present. The trunks are almost invariably charred by fire, and charred resins are found very commonly over the ground surface. We suspect that the deposit was originally covered by a heavy forest which has been removed by fire within comparatively recent time. Toward the interior the vegetation gradually assumes the character of the surrounding forested region. In the western part of the deposit, where the forest is heavy, we thought at first that the ore was of lower grade. It had gradually changed in color from a deep red at the coast to a yellowish brown at the western limit of the deposit, the change correspond-

ing closely with the increase in vegetation. Analyses, however, proved the iron content to be just as high in the earth which supported the heavy forest as in the more highly colored mantle on the bare hills.

Specimens of a half dozen of the plants which are most abundant over the barren portions of the ore deposit were submitted to Mr. E. D. Merrill, botanist of the Bureau of Science, who stated that they belong without exception to the flora of high altitudes in the Philippines.[2] The best-known types had not previously been found below an elevation of from 500 to 600 meters and were commoner at elevations of 1,500 meters, whereas the specimens submitted were all secured at elevations ranging from sea level up to possibly 200 meters. Two of the specimens were evergreens belonging to the pine family, another was an edible blueberry which is common in the highlands of northern Luzon, while the commonest plant observed is the weedlike fern already mentioned. Pitcher plants, some of which produce pitchers of extraordinary size, abound in the region of the iron-ore deposit, but these, also, are found in other parts of Surigao.

GEOLOGY

The iron ores are clayey residual products from the surface decomposition of igneous rocks. They are similar to the laterites in origin found commonly in tropical countries. The parent rock in Surigao is subsiliceous in character and is probably a peridotite, but wherever exposed it is so completely altered as to make the determination of its original character difficult. The outcrops which are most widely distributed consist essentially of serpentine. On the beach, throughout the length of the deposit, rocks of other types are found locally and probably occur as dikes cutting the main rock mass. The dike rocks include diorites, gabbros, and felsitic to porphyritic andesites. Schist has also developed locally, probably in shear zones, and occurs in rare fragments along the beach.

Sedimentary rocks, principally tuff-sandstone and crystalline limestone, overlie the igneous basement, the alteration of which has given rise to the iron ore, and the line of contact between the basement rocks and the overlapping sedimentaries marks the limit of the ore deposit toward the interior. The sedimentaries outcrop on the coast at Capandan southeast of Claver

[2] Unfortunately Mr. Merrill's memorandum containing the classification of these plants was misplaced and because of his absence on leave cannot be replaced in time for publication in this paper.

Point, and the line of contact between them and the ore deposit runs south-southest. Blocks of limestone are found resting on the ore formation on the hill southwest of Capandan. Judging from the character of this limestone, the sedimentaries are probably of Miocene age. An escarpment marks the edge of the sedimentaries and forms a prominent line of hills trending south-southeast back of Capandan. The sedimentary rocks appear on the coast on the southern edge of the ore deposit in the ridge at Carrascal, the line dividing them from the ore deposit passing westward beyond Mount Legaspi. Thus the heavy, broken line which delimits the ore deposit in Plate I marks, also, the line of contact between sedimentary and igneous rocks throughout most of its course. The line approaches more closely to the summit of Mount Legaspi, however, than do the sedimentaries to the west, because the upper slopes of this peak show very little ore. It recurves, also, at its southern extremity to separate the area of alluvium around Carrascal Bay from the iron-ore formation. The numerous small islands which lie off the coast between Capandan and Carrascal are all composed of sedimentary rocks, except Ludguron Island in Carrascal Bay, which is partly covered with iron ore.

CHARACTER OF THE IRON ORE

The ore is principally ferruginous clay, but contains also an abundance of small, round pellets of hydrous iron oxides, as well as fragments or crusts of the parent rock, much altered, porous, and iron-stained, but maintaining their original form. Mineralogically the ore is probably a series of hydrous iron oxides related to limonite. The surface of the deposit is a deep reddish brown, almost crimson at places, but beneath the surface the color is lighter—a yellowish brown—while the transition stage between the ore and the underlying rock is pale green. The thickness of the mantle of ore varies irregularly up to a maximum of about 20 meters. The ore in place is soft and very spongy or mealy. In walking over it one often breaks through the crust into small openings or cavities beneath the surface.

The iron ores of the Nipe Bay region in Cuba appear to be similar in every respect to the iron ore in Surigao, and the reader who desires more detailed information will find elaborate descriptions of the Cuban ores with studies of the various steps in the alteration processes from serpentine to hydrous iron oxides.[3]

[3] The Mayari Iron-Ore Deposits, Cuba, by James F. Kemp, is especially good. *Bull. Trans. Am. Inst. Min. Eng.* (1915), 98, 129.

The chemical composition of the Surigao ore is shown in the following tables. Table I contains the analysis of a sample taken by Mr. Cameron and an analysis of similar ore from Mayari, Cuba, quoted from Kemp.[4]

TABLE I.—*Analysis of iron ore from Surigao Province.*[a]

Constituent.	Surigao ore.	Cuban ore.
	Per cent.	*Per cent.*
Hygroscopic water	13.50	----------
Combined water	6.60	11.15
Silica (SiO_2)	1.04	2.26
Alumina (Al_2O_3)	10.56	14.90
Ferric oxide (Fe_2O_3)	66.80	68.75
Ferrous oxide (FeO)	0.36	0.77
Chromium oxide (Cr_2O_3)	1.15	1.89
Sulphur	trace	----------
Phosphorus	trace	----------
Nickel oxide (NiO)	none	0.74
Total	100.01	100.46
Metallic iron, dry ore	54.29	48.65
Metallic iron, ignited ore	58.20	54.20

[a] Analysis by Francisco Peña, chemist, Bureau of Science.

Two other samples submitted by Mr. Cameron contained 51.92 and 54.15 per cent, respectively, of metallic iron in the dried ore.

The determinations appearing in Table II were made upon drill-hole samples taken by us. The figures show the percentage of metallic iron in the dried ore and in the sintered ore. The latter figure is employed for the purpose of making possible a direct comparison of the Surigao ore with the Cuban ore, which is sintered or nodulized before it is smelted. Sintering is a necessary preliminary to the smelting of clayey ores, and the column containing the figures for the iron content of the sintered ore also shows the proportion of iron which a smelter could expect in ore from Surigao. It is assumed that the Surigao ore will reabsorb about the same quantity of moisture after sintering that the Cuban ores do. Kemp[5] states that the nodulized or sintered Cuban ore contains from 3 to 3.5 per cent of water; therefore the column of percentage of iron in the sintered ore is based on the weight of the ignited ore plus 3.5 per cent for reabsorbed water.

[4] Op. cit., 147. [5] Op. cit., 131.

TABLE II.—*Iron content of Surigao iron ore.*[a]

Drill hole. No.	Drill hole. Depth.	Description of sample.	Loss on ignition; ore dried at 110° C.	Metallic iron in dry ore.	Metallic iron in sintered ore.[b]
	Meters.		*Per cent.*	*Per cent.*	*Per cent.*
		Western edge of deposit south of Taganito: Surface ore	14.76	53.40	60.5
		Central portion of deposit inland from Hinadkaban Bay:			
		Depth—			
1	9	0-3 meters	12.50	47.30	52.2
		3-6 meters	12.70	42.56	47.0
		6-9 meters	12.20	29.59	32.5
		Southern portion of deposit; mainland near Dahikan Bay:			
		Depth—			
10	4	0-3 meters	12.20	31.00	33.0
12	12	0-3 meters	12.50	47.30	52.2
		3-6 meters	11.08	55.75	60.5
		6-9 meters	11.80	42.56	46.6
16	12	0-3 meters	13.34	49.81	55.7
		3-6 meters	13.49	50.89	56.8
		6-9 meters	12.02	54.36	59.7
		9-12 meters	12.13	51.96	57.2
20	8	0-3 meters	11.50	54.50	59.5
		3-6 meters	10.00	49.95	53.6
36	9	Surface	14.10	46.79	52.5
		Southern portion of deposit; peninsula near Dahikan Bay:			
		Depth—			
17	12	0-3 meters	13.05	45.64	50.7
		3-6 meters	11.04	37.16	40.4
		6-9 meters	10.57	48.01	51.9
		9-12 meters	11.93	54.86	60.2
29	3	0-3 meters	13.30	44.45	49.7
33	9	0-3 meters	14.25	48.30	54.4
		3-6 meters	14.45	49.10	55.4
		6-9 meters	13.15	51.40	57.3
		Northern part of ore deposit; inland from Taganito:			
		Depth—			
72	11	0-3 meters	14.16	45.64	51.4
		3-6 meters	12.41	45.63	50.3
		6-9 meters	13.60	42.28	47.3
76	6	0-3 meters	13.60	52.20	58.3
79	9	0-3 meters	15.34	47.39	54.0
		3-6 meters	14.00	48.16	54.0
		6-9 meters	13.57	51.39	57.5
85	6	3-6 meters	14.40	49.98	55.8
		Average	12.87	47.40	52.5

[a] Analyses by T. Dar Juan, A. S. Arguelles, and Francisco Peña, chemists, Bureau of Science.
[b] Calculated on a basis of 3.5 per cent reabsorbed moisture.

The material from each 3 meters of drill hole constitutes a separate sample. Occasional samples were taken from the surface, also. The analyses tabulated are on samples selected as representative of a total of 183 samples, taken from 89 different drill holes. The drill holes were located at regular intervals, usually at the corners of 300-meter squares, and groups of drill holes were distributed over different parts of the ore deposit.

From the foregoing analyses it appears that the average ore from Surigao would contain 52.5 per cent of iron after being sintered or nodulized in preparation for smelting. If two conspicuously poor samples, both of which probably are contaminated with the underlying parent rock, be excluded, the average iron content of the sintered ore becomes 53.9 per cent. Even this figure is somewhat lower than the average iron content of the ore mined at Mayari, Cuba, by the Spanish-American Iron Company. The yearly output of this company averages 48 to 49 per cent iron in the dry ore and 55 to 56 per cent iron in the nodulized ore.[6] Another important difference between the Cuban ore and the ore from Surigao Province is in their respective nickel contents. The average Cuban ore carries about 1 per cent of nickel, while no nickel has been detected in the Surigao ore.

The observation has been made in the Cuban deposits that the iron content of the ore increases for a certain distance below the surface and then declines. The samples from Surigao show a similar change generally, but not in all cases; some holes reveal a progressive decrease from the surface downward. It is notable that the very shallow holes encountered relatively poor ore, while the deepest holes show the best ore. This may be due in part, however, to a tendency to drive the shallow holes farther into the parent rock, proportionally, than in the cases of the deeper holes.

QUANTITY OF ORE

The quantity of ore is estimated upon a basis of the total area of the iron-ore deposit as determined by our reconnaissance surveys and the average depth of the ore as determined by drilling. The Coast and Geodetic Survey base map upon which our surveys are plotted is accurate, but the position of the line which marks the interior limit of the deposit is determined only approximately. The figure for the average depth of the ore is

[6] Kemp, James F., loc. cit., 131.

obtained by dividing the whole deposit into two classes—good areas and poor areas—the boundaries of which were determined by our observations in the field. This classification applies to the nature of the deposit, not to the character of the ore. The average depth of ore in each area is estimated from the results of groups of drill holes in that area. The various areas over which the ore is of good depth (indicated in Plate I) are again divided into two groups, one of which includes two areas which are accessible from Dahikan Bay and the other includes five areas which must be exploited from another base—probably from Taganito.

The total area of the ore deposit is about 100 square kilometers. This figure is less than the area of the deposit as outlined in Plate I by reason of the exclusion of several patches of alluvium and some of the steeper slopes which are not covered by ore. Probably 30 per cent of the deposit, exclusive of the good areas, is so inaccessible and so covered with forest that the ore upon it would have no commercial importance.

The areas classed as good aggregate 30 square kilometers. They include flat-lying portions of the deposit over which the ore is known to be of good depth. The two areas which are accessible from Dahikan Bay, the most feasible base of operations, contain 15 square kilometers.

Four groups of drill holes were located in the areas classed as good: One group of 56 holes placed regularly (some 150 meters, some 300 meters, and some 500 meters apart) in the vicinity of Dahikan Bay; one group of 2 holes in the vicinity of Hinadkaban Bay; and one group of 23 holes, 300 meters apart, in the vicinity of Taganito. One group of 17 holes, spaced at 150-meter intervals, was located in a poor area near Dahikan Bay. It may be objected with some reason that the number of holes and the area over which they are distributed are both limited and are hardly a sufficient basis for judging the whole ore deposit. The result which we obtained, however, both on the chemical character and the thickness of the ore, from widely separated groups of holes, are uniform enough to make us confident of the approximate correctness of our results considered as preliminary estimates. At any rate, the reader, knowing the basis upon which the estimates are made, will draw his own conclusions as to their accuracy.

Of the drill holes located in good areas, 6.8 per cent fell on bare rock, thus encountering no ore; 28.8 per cent encountered from 0.5 to 3 meters of ore; 34.3 per cent encountered from

3 to 6 meters of ore; 21.9 per cent encountered from 6 to 9 meters of ore; 6.8 per cent encountered from 9 to 12 meters of ore; and 1.4 per cent encountered from 12 to 15 meters of ore. The analyses indicate that a few of the holes did not penetrate to the underlying parent rock. On the other hand, some of them went into the parent rock farther than mining operations would extend. Hence, these two possible sources of error in the determination of the average depth tend to balance each other. The holes were always continued until they struck hard rock, and usually represent the actual thickness of the surrounding ore.

Of the drill holes located in poor areas, 29.4 per cent encountered no ore; 58.8 per cent encountered from 0.5 to 3 meters of ore; 5.9 per cent encountered from 3 to 6 meters of ore; and 5.9 per cent encountered from 6 to 9 meters of ore.

Specific gravity determinations on small pieces of the ore indicate that its dry weight in place must be from 1.7 to 2.5 metric tons per cubic meter. This estimated unit weight may appear to be low for an iron ore, but as a matter of fact the Surigao ore is very porous. In the following estimates it will be assumed that 1 cubic meter of dry ore weighs 2 metric tons.

According to these figures the areas of good ore contain 275,400,000 metric tons of ore as follows:

TABLE III.—*Quantity of ore in good areas.*

Average depth (meters).	Quantity.	
	Cubic meters.	Metric tons.
1.75	15,100,000	30,200,000
4.50	46,300,000	92,600,000
7.50	49,200,000	98,400,000
10.50	21,400,000	42,800,000
13.50	5,700,000	11,400,000
Total	137,700,000	275,400,000

If it be assumed that only areas over which the average depth is 3 meters or more can be exploited economically, the total available tonnage becomes 260,300,000. One half of this quantity, or 130,150,000, is fairly accessible from Dahikan Bay as a base.

The quantity of ore included in the area classed as poor is 222,400,000 tons, as follows:

TABLE IV.—*Quantity of ore in poor area.*

Average depth (meters).	Quantity.	
	Cubic meters.	Metric tons.
1.5	61,800,000	123,600,000
4.5	18,500,000	37,000,000
7.5	30,900,000	61,800,000
Total	111,200,000	222,400,000

If it be assumed that only areas over which the average depth is 3 meters or more will prove valuable, the available tonnage in the poor area becomes 160,600,000. Again, if our belief that 30 per cent of the poor area is too remote and too heavily forested to repay exploitation is correct, the total available tonnage over the poor area is 155,680,000, of which 112,420,000 tons form a layer of 3 meters or more in thickness.

In summary, the total iron-ore reserves in the Surigao deposit amount to approximately 500,000,000 metric tons. Of this total quantity about 430,000,000 tons are fairly accessible for mining, although by no means conveniently situated, and 373,000,000 tons are contained in that portion of the ore mantle which is 3 meters or more in thickness. On the flat-topped barren hills which border the coast there are 275,000,000 tons of ore. This ore is comparatively accessible, but is divided into a number of separate areas. That portion of it which is 3 meters or more in thickness amounts to 260,000,000 tons. Finally, from Dahikan Bay, which offers natural harbor facilities, two blocks of ore could be exploited containing an aggregate tonnage of 138,000,000, with 130,000,000 tons forming a deposit 3 meters or more in thickness. However, even from this most favorable base the bulk of the ore must be brought down to sea level from the tops of hills, ranging in elevation from 200 to 400 meters.

COMMERCIAL POSSIBILITIES OF THE DEPOSIT

The Surigao iron ores constitute a natural resource which will probably be more valuable in the future than it is to-day. At present the demand for iron and steel in the Philippines is not sufficient to justify the large-scale operations which would be necessary for the proper exploitation of the Surigao deposits. An ore which is richer in iron is available at Mambulao, Camarines, in adequate quantity and under conditions just as favorable as the conditions which obtain in Surigao. Yet no success

has attended the efforts so far made to exploit the Camarines ore. The Surigao ore possesses an advantage in its freedom from objectionable impurities, such as sulphur and phosphorus, although neither of these elements is injuriously high in the Camarines ore.

The best authorities believe that the Cuban ore, with which the Surigao ore has been compared, will ultimately be exported to Europe as well as to the United States. But one of the features which make the Cuban ore valuable is its nickel content. This metal, so desirable in certain classes of steel alloys, is not present in the Surigao ore. Then, too, the Surigao ore is poorer in iron than the Cuban ore, and while the difference in the iron content is small, it is sufficient to make a difference in the smelting values of the two ores.

If the Surigao deposit is exploited in the near future it will probably be for the purpose of exporting the ore to be smelted elsewhere. The present export tax of 2 pesos per metric ton on ores would make difficult the profitable mining of the ore, even for export. The lack of coke for reduction, as well as the limited market for the product, militate against the development of a local iron- and steel-smelting industry. On the other hand, when in time the Philippine market becomes large enough to justify manufacturing iron and steel from these ores, the problem can probably be solved by utilizing one of the larger streams for hydroelectric power and accomplishing the reduction in the electric furnace with charcoal burned in the surrounding forests.

Dahikan Bay, which is protected from the rough seas common to the eastern coast of Mindanao throughout one half the year, offers the best situation for a base of mining operations. Not only does it afford the only natural harbor facilities in the region, but it is adjacent to the largest area of ore. Power will have to be transmitted from a distance, but this is true, also, of any other possible location. Taganito is another possible base of operations. It has no natural harbor facilities, although there are outlying islands which might prove of value in making a harbor. But it is the logical point from which to mine a large quantity of ore, as it affords a larger area for the plant site than is available at Dahikan Bay and has more water for general purposes, and water for power could be obtained on the upper parts of several rivers which discharge at Taganito.

Wherever mining is attempted in the Surigao deposit, it will be necessary to mine the greater part of the ore on the tops of the hills varying from 150 to 400 meters in elevation and to transport the mined ore down steep slopes to sea level.

ILLUSTRATIONS

TEXT FIGURE

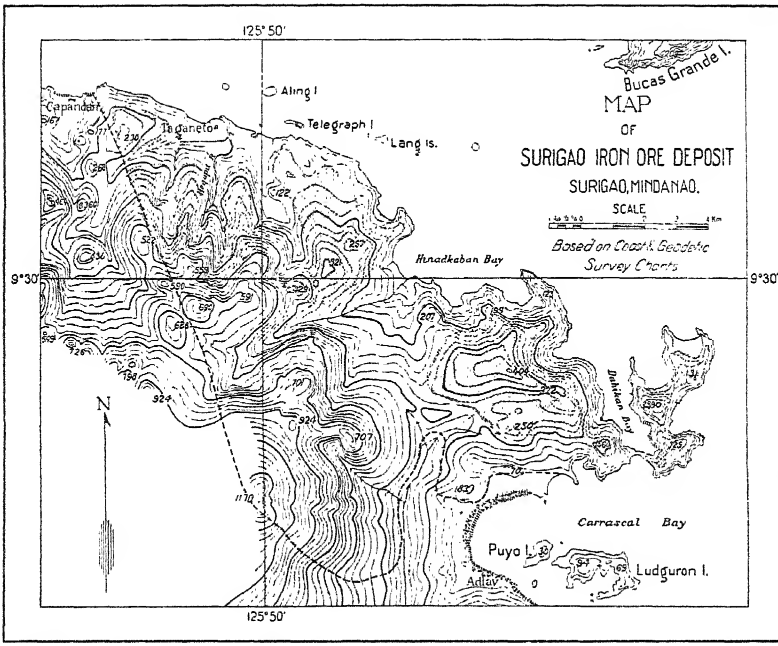


PLATE I. TOPOGRAPHIC MAP OF IRON-ORE DEPOSIT IN SURIGAO, SHOWING (RED CROSS-HATCHED AREAS) BEST PARTS OF DEPOSIT.

THE PHILIPPINE

JOURNAL OF SCIENCE

A. CHEMICAL AND GEOLOGICAL SCIENCES
AND THE INDUSTRIES

VOL. X NOVEMBER, 1915 No. 6

THE LEATHER INDUSTRY OF THE PHILIPPINE ISLANDS[1]

By VICENTE Q. GANA

(*From the Laboratory of General, Inorganic, and Physical Chemistry, Bureau of Science, Manila, P. I.*)

TWO PLATES

There exists in the Philippine Islands a considerable, but very primitive, tanning industry. The methods now in use have not undergone substantial modification since they were introduced by the Chinese, probably several centuries ago. Consequently the leather produced is inferior in quality, especially so since tanning in a tropical country involves difficulties not encountered elsewhere. There is no obstacle to a great expansion of this industry. The leather market is good, and additional supplies of the necessary materials can be had in considerable quantities and at fairly reasonable prices. Therefore, in order to stimulate the industry, an extensive study of the existing industry and some practical experiments using improved methods have been carried on.

Data regarding the leather industry furnished by the provincial treasurers are given in Table I.

TABLE I.—*Number and output of tanneries of the Philippine Islands.*

Locality.	Tanneries.	Tanned hides produced.	Locality.	Tanneries.	Tanned hides produced.
Manila	8	39,050	Tayabas	2	250
Bulacan	11	36,000	Batangas	19	220
Iloilo	3	5,929	Zamboanga	1	216
Cebu	4	4,401	Nueva Ecija	4	164
Pangasinan	11	2,600	Sorsogon	1	120
Albay	4	1,320	Antique	2	70
Ilocos Sur	37	1,130	Cavite	4	65
Ilocos Norte	13	1,114	Cagayan	17	54
Ambos Camarines	3	270	Capiz	22	22
Rizal	1	250	Total	167	93,245

[1] Received for publication May 10, 1915. This paper is being issued in Spanish.

136791

Although doubtless lacking great accuracy, the statistics show that the tanning industry produces leather to the value of from 1,500,000 to 1,800,000 pesos [2] per annum. On the whole, the figures regarding production are believed to be too low.

THE LOCAL LEATHER MARKET

There is a large and increasing local demand for leather and leather goods which is met almost entirely by importation. Table II shows the Philippine customs invoice value of imports of leather and manufactures thereof for several years.

TABLE II.—*Invoice value of imports of leather.*

Year.	Pesos.	Year.	Pesos.
1903	1,373,572	1909	988,276
1904	985,070	1910	1,520,926
1905	986,334	1911	1,988,382
1906	922,440	1912	2,051,614
1907	958,268	1913	2,380,246
1908	1,343,924		

The actual value of these goods is unquestionably several times larger than the invoice value given in the table. A gradual increase has occurred in almost every item included in these figures. Most notable, however, is the increase in the importation of boots and shoes. The introduction of European customs of dress may safely be expected to maintain or accelerate this rate of increase for several years. Table III gives the classification of the leather and manufactures thereof imported during the years 1912 and 1913, as shown by the annual reports of the Collector of Customs. It will be noted that the item boots and shoes constitutes nearly 60 per cent of the total.

TABLE III.—*Classification and value of Philippine imports of leather and manufactures thereof for the fiscal years 1912 and 1913.*

	1912	1913
	Pesos.	*Pesos.*
Boots and shoes	1,173,904	1,390,864
Sole leather	102,524	200,016
Upper leather	109,886	256,534
All other	519,920	253,758
Belting	65,662	59,862
Harness and saddles	79,718	163,594
Pocketbooks, purses, wallets, and hand bags		55,618
Total	2,051,614	2,380,246

[2] One peso Philippine currency equals 100 centavos, equals 50 cents United States currency.

In recent years a number of boot and shoe factories have begun to operate in Manila and they are still expanding. As they consume imported sole and upper leather exclusively, the demand for satisfactory grades of these goods is likely to increase very markedly. It is to these classes of leather that the prospective tanner in the Philippines should devote his first and main attention.

In addition to the industry just mentioned, which uses imported leather and which is conducted by Europeans and Americans, there is an even larger leather-working business among the Filipinos and Chinese. It is carried on in small shops or as a household industry. Its products include cheap shoes, sandals, harness, saddles, bags, etc., made almost exclusively of leather tanned in the Islands. The improvement of domestic leather would, of course, be of great advantage to these industries.

The present prices of staple leathers on the local market are approximately as follows:

TABLE IV.—*Prices of staple leathers on the Manila market.*

Article.	Per piece.	Per kilogram.
	Pesos.	*Pesos.*
Domestic, tanned, native cattle hides	13–20	[a] 1.40–1.80
Domestic, tanned, Australian cattle hides	16–24	[a] 1.60–1.90
Imported sole leather	[a] 40–50	2.00

[a] Calculated from actual market prices and the average weight of hides.

Quality considered, native leather commands a much better price per kilogram than imported. This arises from the Filipino custom of buying leather by area rather than weight. The loss to the Filipino tanner in producing undertanned leather is very apparent in the prices per piece. There is no exportation of leather or leather goods from the Philippines.

RAW HIDE SUPPLY

In spite of the inroads which rinderpest has made upon the cattle-raising industry of the Philippines and of the strict limitations placed in recent years on the importation of animals from abroad, with the consequent shortage on the local market, very many hides and skins go to waste each year.

There has been difficulty in getting reliable information about the supply of hides and skins from domestically slaughtered animals, but from figures of the Bureau of Agriculture it appears that 11,133 sheep, 69,851 goats, 1,019 horses, 36,935

cattle, and 17,890 carabaos were slaughtered in the Philippines during the calendar year 1913. These animals would furnish roughly 90,000 skins and 56,000 heavy hides. The number of available raw hides, according to the reports of the treasurers of the several provinces mentioned in Table I, is 54,057.

Hides and skins are bought and sold by the piece. At market centers salted hides of Australian cattle average about 16 pesos and of native or Chinese cattle about 10 pesos. This amounts to about 65 centavos per kilogram for the former and 60 centavos per kilogram for the latter. However, in many provinces cattle hides can be bought as low as 1 peso per piece and average less than 5 pesos. They are frequently not removed from the animals. There is a small production of dried hides which are exported to Hongkong and British East Indies for the manufacture of glue. Table V gives the value of such exports.

TABLE V.—*Exports of dried hides from the Philippine Islands to Hongkong and British East Indies.*

Year.	Pesos.	Year.	Pesos.
1907	30,336	1911	22,626
1908	25,710	1912	22,626
1909	27,920	1913	29,492
1910	46,074		

Very little care is exercised in the method of preserving hides for the market. Systematic salting is not in general use, and many hides reach the tanner in a semiputrid condition. The process of salting hides is a very simple one and consists in the even distribution of salt, about 25 kilograms for every hundred kilograms of hides, over the flesh side of the hides in a layer so thick that solid salt always remains. The hides should be stacked in such a way that the draining away of any resulting brine will be prevented. Hides which are salted with reasonable care keep very well, even in this climate.

In addition to the domestic product, there has been a considerable importation of raw hides and skins into the Philippines during the last four or five years. The imported hides come almost exclusively from China. Table VI gives the figures of the importation of raw hides and skins.

TABLE VI.—*Value of imports of raw hides into the Philippine Islands.*

Year.	Pesos.	Year.	Pesos.
1907	9,056	1911	36,210
1908	19,906	1912	151,222
1909	[a]39,326	1913	62,428
1910	[b]76,772		

[a] From China. [b] Mostly from China.

The weights and prices of these imported hides are given in Table VII.

TABLE VII.—*Weights and market prices of raw salted hides in Manila.*

Variety.	Weight.	Price per hide.
	Kilo-grams.	*Pesos.*
Australian cattle hides	20–25	13–16
Chinese cattle hides	15–21	7–12
Carabao hides	18–35	6– 8
Native cattle hides	15–30	5–15

TANNING MATERIALS

The only tanning materials used in the Philippines are the barks of the various species of mangrove (Rhizophoraceae or mangrove family) and the camanchile tree (*Pithecolobium dulce* Benth.). The former are very plentiful and cheap, selling for about 25 pesos per metric ton. In spite of this fact and in spite of their high tannin content, mangrove barks are not extensively used in the Philippines outside of the city of Manila. This is primarily because of the resulting harshness and dark red color of leather tanned with mangrove alone. However, good light-colored leathers can be produced by combining camanchile and mangrove, as I have demonstrated by experiments which will be discussed later. The mangrove barks have been considerably studied[3] and are widely used in Europe and America. Their use may well be extended in the Philippines.

Camanchile bark is used almost exclusively by Filipino tanners, who prefer it on account of the light-colored leather it produces. Because of this demand the price of air-dried camanchile bark has risen as high as 10 pesos per 100 kilograms. The tree is widely scattered throughout the Islands, although nowhere systematically or extensively grown. The present annual consumption of bark amounts to about 1,500 tons. Exhaustion of the supply is threatened, as the trees are commonly killed by too extensive stripping of the bark. The bark is brownish gray and rough outside and reddish brown inside. It produces dull but light-colored leather, which reddens on exposure to light. An infusion of it contains a tannin of the catechol class, which

[3] Bacon and Gana, *This Journal, Sec. A* (1909), 4, 205; Williams, R. R., ibid. (1911), 6, 45. The waste wood can be utilized for firewood [Cox, Alvin J., ibid. (1911), 6, 1], or for destructive distillation, as shown by experiments now under way.

gives a green-black precipitate with iron salts, a light brown precipitate with bromine water, and crimson line when in contact with one drop of concentrated sulphuric acid. Upon analysis a representative sample of the bark gave the following results, calculated on water-free material: Total extract, 34.77 per cent; nontannin, 9.41 per cent; tannin, 25.36 per cent.

Camanchile bark infusion soon ferments and decomposes in this climate, resulting in the destruction of tannins, the development of a disagreeable odor, and a thickening of the liquid due to a viscous gelatinous formation which accumulates and grows on the surface. A few experiments with phenol as a preservative showed that a concentration of 0.01 per cent does not check the fermentation appreciably, as in a control infusion the tannins were destroyed, the color became a deep wine red—at least three times as intense as the original red orange—a somewhat penetrating smell was given off, and a gelatinous formation and a slimy sediment developed, which made the infusion viscous. After four months the loss of tannin amounted to 15 per cent of the total tannin content. An infusion containing 0.1 per cent phenol at the end of the same period showed a practically unaltered tannin content and an acidity equal to 0.0714 gram acetic acid per 100 cubic centimeters. A little fermentation which soon ceased had produced some slimy sedimentation, but had not altered the appearance or odor of the clear supernatant infusion.

Camanchile bark contains irritating principles, which are believed by laborers in the tanneries to indicate roughly the strength of infusion. Infection of the eyes, producing weakening of the sight, and irritation and swelling of the lids are attributed to them.

Through the coöperation of Dr. Fred W. Foxworthy, of the College of Forestry at Los Baños, who collected and sent me the material, I was enabled to examine several barks and fruits which have not as yet been used as tanning materials. The results are presented in Table VIII.

Of these tanning materials none seems particularly promising, either on account of the insufficient supply or on account of the low tannin content.

THE FILIPINO PROCESS OF TANNING

As has been stated previously, the Filipino process of tanning is very primitive and produces a very inferior grade of leather. It was desired to make a study of this process in order to point out its prime defects and to suggest improvements which might be put into effect without materially increasing the investment

TABLE VIII.—*Analyses of miscellaneous tanning materials.*

Sample No.	Material.	Botanical name.	Distribution.	Precipitate with ferric salts.	Precipitate with bromine water.	Color on contact with concentrated sulphuric acid.	Moisture.	Tannin.	Non-tans.	Character of leather produced.
							Pr. ct.	*Pr. ct.*	*Pr. ct.*	
1	Cateban bark	*Quercus* sp	Scattered in hilly districts.	Blue-black	Brown	Red-brown	10.2	10.9	4.2	Rather hard; hazelnut brown.
2	Ulayan bark	do	do	do	do	do	10.2	11.0	3.9	Satisfactory texture; hazelnut brown.
3	Balinghasay bark	*Buchanania arborescens.*	Scattered generally	Green-black	do	Deep brown	8.7	8.2	7.6	Hard and somewhat harsh; dark reddish brown.
4	Pagsahinging bark	*Canarium villosum*	Common in hilly districts.	do	Yellowish brown.	Pink	8.0	2.8	5.5	Thin and soft; pale brown.
5	Calamansanay bark	*Nauclea calycina*	Scattered in hills	do	Brown	Brown	8.8	6.5	7.6	Thin; very dark red.
6	Ligas bark [a]	*Semicarpus accuminatissima.*	Scattered generally	do	Yellowish brown.	Pink	8.0	2.2	4.3	Thick; reddish brown.
7	Sacat fruit	*Terminalia nitens*	do	do	Light brown	Reddish brown	8.9	19.8	16.3	Thin, smooth grain; dark color.

[a] The sap of this tree produces blisters on the skin.

in equipment or supplies. For this purpose the tanning industry as conducted at Meycauayan, Bulacan, was chosen for study. Meycauayan is one of the largest leather-manufacturing centers in the Philippines, and its methods are fairly representative of those of the Islands as a whole. Eleven tanneries are located there, with an aggregate output of 36,000 pieces per year, consisting almost wholly of cattle hides. These include practically the entire product of the Government slaughterhouse at Sisiman and an almost equal number of imported hides from Hongkong. A few carabao hides are tanned, but the Filipino tanners are not willing to attempt the tanning of these hides except under exceptional circumstances. On account of their thickness they are very hard to tan and they are liable to putrefaction. Therefore they are usually split, and very commonly only the grain side is tanned, the remainder being discarded or used for glue.

The leather produced by the Filipino process is soft and pliable and, in general, is very much undertanned. It is characterized by an unpleasant odor, especially when wet. This leather lacks the firmness and durability desirable in sole leather and, at the same time, is too thick for first-class upper leather.

The salted hides, as received at Meycauayan, are usually in good condition, not showing evidences of decay or having particularly offensive odors. They are laid in packs of from 17 to 20 and are soaked for about eight hours in water in the bed of a river. They are then removed to lime pits of masonry construction, which are usually placed, in a series of from 10 to 20, in the open air without protection from sun or rain. The usual dimensions of a pit are 1.7 meters by 0.9 meter, with a depth of 0.8 meter. A pack of 20 hides is laid in the pit, 25 liters of lime and sufficient water nearly to fill the pit being used for the liming process. The water used is taken either from the river or from shallow surface wells near by.

The method of preparing the lime liquors and laying the hides in the liming pits is as follows: The lime is mixed with water, and the gravel and the coarser particles are removed with a bamboo sieve. A hide is laid in this liquor, folded lengthwise with the hair outside. Other hides are placed on top in the same manner, until the pack is complete. The hides are left in the lime pits for from ten to fifteen days, during which time they are overhauled three or four times. At each overhauling the order of laying is reversed, so that the upper hide in the pack is laid at the bottom, and so on. The exact duration of the liming process is determined by the loosening of the hair and the degree of plumping of the skin. Frequently after the

hides have been removed from the lime pits and have been fleshed and dehaired, they are again returned to the lime liquors if the tanner believes more plumping is desirable. The lime liquors are used only once.

The limed hides are taken to the river and depilated, fleshed, and cleaned by scraping the hide with a blunt knife to take out as much lime as possible (Plate II, fig 1). They are left in the river under water for a few hours to be freed from lime and are then ready for the tan pits. Except the hair, all the fleshings and scrapings and even parts of the pelt itself go to the refuse basket. All this waste is mixed with the lime and pressed into cakes, dried in the sun, and sold for 9 pesos a picul [4] to glue makers. This return is customarily divided into one half for the tanner and the other half for the laborers.

The tan pits, partly above the surface of the ground, under cover of a large, open shed, are walled up with adobe stone [5] and ordinary mortar. Each pit measures 1.9 meters by 1 meter with a depth of 1.2 meters and holds 20 native or Chinese cattle hides or 17 Australian hides. For each such pack a tan bark infusion is prepared by placing from 500 to 600 kilograms of chopped camanchile bark in the tan pit and macerating it for three days with about 1,200 liters of a liquid consisting of two thirds fresh water from a surface well and one third old, used tan liquor. A date for making the infusion is so chosen that the dressed hides will be ready for the tan pits on the fourth day. The bark is then removed and used for laying between the hides.

In laying away the pack, the workman places a hide smoothly grain side up, so that about half its surface rests on a layer of bark in the bottom of the pit. Another layer of bark is spread over this surface, and the other half of the hide, which has in the meantime been supported in the hands, is folded along the middle of the back down upon the bark. After another layer of bark has been placed over this hide, the remainder of the pack follows in the same manner, and the whole of the bark infusion is added. The pack is handled and the hides are kneaded with bare feet four times during tannage, usually once on each of the first four days. After each handling the hides are returned to the pit as before. Sometimes a fifth handling and kneading or even a sixth is resorted to when necessary to prevent putrefaction.

The object of kneading is to compress and distort the hide

[4] One picul is equivalent to 63.25 kilograms.

[5] Porous volcanic tuff.

fiber and to hasten the absorption of the tannin. Such is the effect of kneading that the hides are almost half "struck" by the fourth day. They are then laid away in the tan pits for six weeks to complete the tannage. After this, if they are not to be sent to market immediately, they are laid in pits, called *tingalan,* with old, exhausted tan liquor. Sometimes they are left here for years. When required, they are taken to the river, thoroughly washed and cleaned, stretched on sticks, and exposed to direct sunlight. When dry, they are sent directly to the market without further treatment.

DEFECTS OF THE FILIPINO PROCESS

The process outlined above is very inefficient in many respects. In a study of the process the following defects proved to be among the most significant:

1. The putrefaction of the hides during the process with consequent loss of hide substance.
2. Waste in tanning materials.
3. Undertannage of the product.
4. Imperfect drying and finishing.

Of these defects by far the most important is that of putrefaction. During the rainy season this is especially difficult for the tanner to prevent, and it is commonly the custom to shut down the tanneries almost completely during that period. The decay is evidenced by a very disagreeable odor which not only develops in the leather itself, but which also pervades the entire tannery and becomes almost suffocating. Skins in which putrefaction occurs tan on both exterior surfaces, while the interior of the hide liquefies. The pelt commonly splits into grain and flesh sheets. The Filipino tanners attribute the putrefaction to dilute tan liquors, which they believe are caused by the use of barks collected during the rainy season. Usually the putrefaction occurs most markedly during the first days of tannage, and at this stage soft, gray spots, which frequently suppurate, may develop. Such spots do not tan at all, and, of course, the entire skin is ruined thereby. Aside from this ruining of the skins by putrefaction, a less extensive decay prevents proper plumping and swelling of the hides and consequent proper absorption of tannin. For this reason it is almost impossible for Filipino tanners to tan thick hides.

The Filipino tanners endeavor to control this putrefaction by adding large quantities of fresh bark to the tan pits and by more frequent kneading of the hides. This procedure, however, is

very ineffective, especially so since the tanner often fails to detect decay until it has proceeded beyond remedy.

The obvious measures to be taken to prevent this difficulty consist simply in greater cleanliness during the entire process. Tan pits, handling floors, and the like should be frequently cleaned and disinfected. Water free from pollution or unusual amounts of mineral matter is also a necessity. The river, on which the tanneries of Meycauayan are located, flows into Manila Bay and is subject to tidal variation. It is, therefore, decidedly brackish and falls far short of what is to be desired in a water for this purpose. Table IX presents an analysis of this water.

TABLE IX.—*Analysis of Meycauayan River water.*

[Numbers represent parts per million.]

Physical characters	brownish yellow with salt taste
Reaction	alkaline
Total solids	52,672.0
Appearance on ignition	blackening and evolution of hydrochloric acid
Free or saline ammonia	0.37
Organic or albuminoid ammonia	0.68
Oxygen consumed	50.00
Chlorine	26,284.4
Equivalent to common salt	43,313.7
Nitrogen as nitrates	trace
Nitrogen as nitrites	nil
Silica (SiO_2)	25.6
Oxides of iron and aluminium (practically all Al).	21.0
Oxide of calcium (CaO)	809.0
Oxide of magnesium (MgO)	2,909.3
Sulphuric anhydride (SO_3)	2,706.7
Total hardness:	8,663.7
Permanent	8,571.2
Temporary	92.5
Bicarbonic acid radical (HCO_3)	142.1
Carbonic acid radical (CO_3)	nil
Free carbon dioxide (CO_2)	4.4

Aside from the large amount of mineral matter present, this water is also objectionable on account of the large quantities of putrefying organic matter ordinarily found in it. A loop of water invariably produced liquefaction in serum and gelatin tubes within forty-eight hours' incubation at ordinary temperature.

Table X gives the analysis of a typical sample of water from

surface wells in this locality such as are used for making up tan liquors.

TABLE X.—*Analysis of water from a surface well at Meycauayan.*

[Numbers represent parts per million.]

Physical character	normal
Reaction	neutral
Total solids	946.0
Appearance on ignition	evolution of hydrochloric acid
Free or saline ammonia	0.048
Organic or albuminoid ammonia	0.068
Clorine	203.6
Nitrogen as nitrates	trace
Nitrogen as nitrites	0.016
Silica (SiO_2)	39.7
Oxides of iron and aluminium (largely Al).	48.0
Oxides of calcium (CaO)	165.0
Oxides of magnesium (MgO)	20.6
Sulphuric anhydride (SO_3)	41.1
Bicarbonic acid radical (HCO_3)	179.2
Free carbon dioxide (CO_2)	13.2
Total hardness:	486.6
Permanent	351.0
Temporary	135.6

Analyses of the liquors used at various stages of the process show very clearly the progress of putrefaction and loss of hide substance. The lime used is made by burning sea shells; it has a total alkalinity equivalent to about 70 per cent calcium hydroxide. An analysis of a typical lime liquor, after removal of the hides, is shown in Table XI.

TABLE XI.—*Lime liquor from a Filipino tannery after removal of the hides.*

	Grams per 100 cubic centimeters.
Nitrogen as ammonia	0.0457
Equivalent hide substance	0.266
Total hide substance	0.987
Unchanged hide substance	0.721

These figures show that nearly 8 kilograms of dissolved hide substance are lost from each pack of twenty hides weighing approximately 230 kilograms, which is equivalent to about 3.5 per cent of the weight of the hides.

Fresh lime liquors about 2 days old are almost sterile, but easily become contaminated by the surface drainage. When 1 week old a loopful of lime liquor will liquefy gelatin within six

days' incubation at ordinary temperature. The lime liquors invariably have a strong ammoniacal odor after two days in contact with hides.

A piece of green pelt from a tannery, weighing about 2 kilograms after dehairing and fleshing, was kept in 2 per cent aqueous solution of phenol. On the fourth day the hide substance dissolved in the liquid was found to be 2.66 grams, or 0.133 per cent of the wet pelt. The phenol solution was changed for a fresh one which, after nineteen days, gave but a faint precipitation ring with a tan infusion. This same phenol solution, after four and a half months in contact with the hide, gave a much stronger precipitation ring, which must be due, not to any further decomposition, but probably to the outward diffusion of dissolved hide substance previously developed inside of the pelt. There cannot have been any putrefaction in the phenol solution, as demonstrated by pieces of the same pelts which remained unaltered in acid and alkaline bouillon tubes for nearly six months. This soluble hide substance is the product of bacterial activity in the pelt.[6]

Pelt which had been limed, fleshed, and dehaired by the usual process of the Filipino tanner, after being kept for one month in 2 per cent phenol solution, gave on analysis the results included in Table XII.

TABLE XII.—*Analysis of limed, fleshed, and dehaired pelt.*

Substance.	Calculated on the basis of green pelt.	Calculated to a water-free basis.
	Per cent.	*Per cent.*
Water	71.50	----------
Nitrogen	4.23	17.3
Equivalent hide substance	27.70	97.2
Lime etc.	0.80	2.8

The liquefying bacterial conditions of the tannery liquors have been determined by means of serum and gelatin media tubes. These tubes were inoculated with one loopful of the tannery liquor and incubated at ordinary temperature—about 30° C. The time period required for the liquefaction of the media is noted in Table XIII.

[6] Brunton and MacFadyen, *Proc. Roy. Soc. London* (1890), 46, 542–53.

TABLE XIII.—*Liquefaction of the media due to liquefying bacteria at a Filipino tannery.*

Description of sample.	Days to liquefy with one loopful of sample.	
	Serum.	Gelatin.
River water used for washing hides	2	
Do		2
Do		2
Lime liquor 2 days old	7	
Do		20
Lime liquor 1 week old		6
Native tan liquor 1 month old	2	
Native tan liquor		2
Do		2
Native tan liquor, strong from covered pit		8
Fresh tan liquor		8
Artesian-well water as delivered at tannery		15
Suspender liquor (my experiment) mixed with 10 per cent native tan liquor		3
Do		6
Liquor from layer No. 1 (my experiment) [a]	3	
Do	13	
Liquor from layer No. 1 (my experiment), from covered pit		15
Fresh tan liquor made with artesian water	10	

[a] In this case the workmen were allowed to contaminate the liquor by wading in it with bare feet still wet with liquors from poluted vats, according to the usual practice. Contrast the three days required to liquefy the serum with the following experiment where thirteen days were required. The only difference is that in the second case I insisted that the workmen first wash their feet in clean water before entering the vats.

The data demonstrate that the tan liquors of the Filipino process generally contain abundant putrefying or liquefying bacteria. Even in the case of pelts that had been washed in 0.5 per cent phenol baths, liquefaction ensued within forty-eight hours when immersed in such liquors. The smell of the leather and tan liquors is due to this putrefaction.

Infusions of fresh camanchile tan bark in pure water are generally practically devoid of liquefying bacteria, as liquefaction of inoculated serum and gelatin media occurs only after from forty-two to seventy-five days of incubation. However, the infusion of this tan bark is quite neutral in its action toward liquefying bacteria. It does not kill them. On the other hand, bacteria do not grow in it except when there is enough proper nourishment present in the form of other suitable substances. In the latter case the multiplication and activity are great in a warm climate.

The tannins, like common salt, do not destroy bacteria, but check the putrefaction of hide substance. Common salt prevents

the putrefaction by extracting water from the hide, while the tannins convert the hide into imputrescible leather. The work of the salt is transient, while that of the tannins is permanent.

An experiment was performed to determine the resistance to, and growth of, liquefying bacteria in camanchile bark infusion at a temperature between 27° and 32° C. Tan infusions were inoculated with tannery liquors, and subsequently a loopful of each was transferred to serum and gelatin media tubes. The periods of time required for liquefaction are given in Table XIV.

TABLE XIV.—*Effect of tan infusions on liquefying bacteria.*

Liquor tested.	Days to liquefy.			
	Serum.		Gelatin.	
	Incipient liquefaction.	Complete.	Incipient liquefaction.	Complete.
Fresh control infusion		42		
Control infusion 1 day old			23	26
Control infusion 3 days old			(a)	(a)
Infusion 1 day after inoculation with river water	5	15		
Do			1	8
Infusion 3 days after inoculation with river water	4	10		
Do			10	14
Infusion 6 days after inoculation with river water	5	11		
Do		10		
Infusion 1 day after inoculation with native tan liquor	4	6		
Do	5	6		
Infusion 8 days after inoculation with native tan liquor	3	4		
Do			10	12
Infusion 3 days after inoculation with native tan liquor	4	10		
Infusion 6 days after inoculation with native tan liquor			4	10
Layer liquor No. 1 (my experiment)				3
Do	4	9		

[a] No liquefaction in seventy-five days.

In this experiment the gelatin tubes were more resistant to the action of the liquefying bacteria than the serum tubes, thus illustrating the fact which must always be borne in mind by a tanner that blood remaining in the hides and skins is one of the causes of speedy putrefaction. Even with fresh and strong tan infusion liquefying and other bacteria will thrive and are sure to do mischief provided there is enough proper food for them.

The waste of tanning material is due almost solely to the Filipino practice of chopping rather than grinding the bark. As the price of camanchile bark is steadily rising and constitutes an item of very large expense to the tanner, any methods for

more effective utilization of the material would be very practical. Tan bark is never ground, but chopped with a heavy, curved knife into pieces about 3 by 4 centimeters in size, which are much too large to permit complete extraction of the tannin. This practice results in a large waste of material, as may be seen from determinations included in Table XV.

TABLE XV.—*Analyses of fresh and "spent" camanchile bark.*

Condition of bark.	Moisture.	On dry basis.		
		Total extract.	Nontannins.	Tannins.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
Fresh	10.34	34.77	9.41	25.36
Used	12.64	23.63	8.31	15.32

In this case only 39.6 per cent of the total tannins contained in the bark was used by the tanners, while the remaining 60.4 per cent was thrown away in the "spent" bark.

Undertannage of leather is one of the chief causes of an unsatisfactory product. This is produced in part by insufficient plumping of the hides, in part by the use of coarse bark in making infusions, but principally because of false economy in the use of the bark. In examining the tan liquors in any Filipino tannery, it will be noted that they are uniformly much too weak, except at the very beginning of the process. In fact, the first tan liquors, corresponding to suspender liquors, are the strongest which are used in the process. This, of course, produces rapid tanning of the surface and, to a great extent, prevents thorough tanning of the interior of the hide.

In determining the percentage of tannin in the tan liquors, specific gravity tests were found to be very unreliable, especially in the case of the older liquors. Large quantities of mineral matter are introduced from the brackish river water and from the hides themselves which are insufficiently delimed. Deliming is rarely effective, as is clearly indicated by the red coloration produced when a drop of a phenolphthalein solution is placed on the surface of the hide.

A piece of delimed hide just ready for the tan pits, after being placed in river water with sufficient formaldehyde to preserve it, was found to be still well impregnated with lime after forty-eight hours. The specific gravity of the river water itself is 1.029. Table XVI shows the specific gravities of tan liquors at various stages of the process.

TABLE XVI.—*Specific gravities of Filipino tan liquors.*

Sample No.	Age.	Contact with pelts.	Specific gravity.
	Days.	*Days.*	
1	5	1	1.022
2	4		1.022
3	6		1.022
4	8	5	1.021
5	3		1.011
6	6		1.016
7	8	5	1.019

Analyses of tan liquors are given in Table XVII.

TABLE XVII.—*Analyses of Filipino tan liquors.*

Sample No.	Stage of process.	Specific gravity.	Acidity as grams acetic acid per 100 cc.	Grams per 100 cc. of the liquor.				
				Ash.	Organic matter.	Sus-pended matter.	Nontans.	Tannin.
1	First day	1.010	0.15	0.79	1.59	0.38	1.39	0.61
2	Fourteenth day	1.018	0.09	2.22	1.64	0.47	3.30	(a)
3	Sixth week	1.018	0.17	1.64	2.41	1.41	2.59	(a)
4	Third day, 20 per cent extra strength.	1.022	0.06	2.03	1.86	(b)	3.22	0.67
5	Half completed	1.019					3.20	0.34

[a] Trace. [b] Undetermined.

The tannin in these liquors is strikingly low, and the nontans, especially the mineral matter, are very high, as is to be expected when brackish water is used. The analyses of the ash of Filipino tan liquors is given in Table XVIII.

TABLE XVIII.—*Analyses of the ash of Filipino tan liquors.*

[Grams per 100 cc. of liquor.]

Sample No. [a]	Silica (SiO_2).	Oxides of iron and aluminium (Fe_2O_3 Al_2O_3).	Oxide of iron (Fe_2O_3).	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chloride and carbonate of sodium plus phosphoric anhydride.
1	0.006	0.026		0.061	0.034	0.039	0.62
2	0.009		0.131	0.093	0.145	0.064	1.77
3	0.030	0.089		0.133	0.102	0.074	1.21
4	0.008	0.039		0.135	0.167	0.078	1.60

[a] The samples correspond to the tan liquors in the previous table.

In addition to the mineral matter the organic nontans are in considerable part nitrogenous materials. The quantity of nitrogenous materials in representative tan liquors is shown in Table XIX.

TABLE XIX.—*Nitrogen content of Filipino tan liquors.*

[Grams per 100 cc. of the liquors.]

Sample No.	Nitrogen as saline ammonia.	Equivalent hide substance.	Total nitrogen.	Equivalent hide substance.
1	0.0430	0.234	0.062	0.343
3	0.0405	0.223	0.077	0.422
5	0.0980	0.540	0.137	0.754

Tests show that extract of camanchile bark contains considerable quantities of nitrogenous material, and a correction must, therefore, be made. Table XX gives the nitrogen contents of the samples in the preceding table and of a fresh camanchile bark infusion calculated as hide substance in per cent of total solids.

TABLE XX.—*Nitrogen contents of Filipino tan liquors calculated as percentage of total solids.*

Sample No.	Saline ammonia as hide substance.	Total nitrogen as hide substance.	Organic nitrogen as hide substance.
1	11.70	17.17	5.47
3	8.45	15.99	7.54
5	15.20	21.38	6.18
Fresh	1.74	6.60	4.86

DEMONSTRATION OF SIMPLE, EFFICIENT IMPROVEMENTS IN THE FILIPINO TANNING PROCESS

Bearing in mind the facts that Filipino tanners do not possess sufficient capital to purchase expensive equipment and that they are indisposed to abandon completely the methods they have used for generations and the cheap labor which they can obtain, an endeavor was made to find simple, inexpensive methods of improvement. In the main this was accomplished without serious difficulty. The improvements in the process are very striking, although no doubt they could be still further increased, especially by additional modification of equipment. The follow-

ing method was put into effect in a Filipino tannery which was then operating under the old methods. This was done as an object lesson, in spite of the unfavorable circumstances which it was anticipated would be encountered. A leather resulted which was odorless, firm, and entirely satisfactory as a sole leather. For this purpose nine hides were chosen as indicated in Table XXI.

TABLE XXI.—*Hides used in tanning experiment.*

	Kilos.
Australian cattle hide:	
No. 1	16.5
No. 2	23.5
No. 3	24.0
Chinese cattle hide:	
No. 1	19.0
No. 2	16.0
No. 3	19.0
No. 4	21.5
No. 5	18.5
No. 6[a]	25.5

[a] Carabao.

The hides were washed in fresh, clean water supplied from a near-by artesian well. The washing was repeated five times and, together with soaking, required seven hours.

TABLE XXII.—*Analysis of the artesian-well water.*

[Numbers represent parts per million.]

Physical characters	normal
Reaction	alkaline
Total solids	274.0
Appearance on ignition	little blackening
Free or saline ammonia	0.074
Organic or albuminoid ammonia	0.026
Chlorine	4.8
Nitrogen as nitrates	nil
Nitrogen as nitrites	nil
Silica (SiO_2)	45.0
Oxides of iron and aluminium	trace
Oxide of calcium (CaO)	6.0
Oxide of magnesium (MgO)	little
Sulphuric anhydride (SO_3)	trace
Total hardness:	10.7
Permanent	10.7
Bicarbonic acid radical (HCO_3)	183.0
Carbonic acid radical (CO_3)	15.0

This water is almost sterile as it comes from the well and was very little contaminated in carrying to the tannery. The hides were next placed in a pit with 40 liters of lime and 400 liters of artesian water, and were left for eight days, during which time they were handled five times.[7] They were then fleshed and dehaired and placed in a 1 per cent phenol solution for twenty-four hours. A bath in a 0.2 per cent solution of sulphuric acid for fifteen minutes followed, for the purpose of neutralizing the surface lime of the pelts. They were placed in a suspender containing very weak, fresh tan liquor, with a specific gravity of about 1.000 at ordinary temperature, and whose strength and acidity were increased every day during ten days up to 1.004 specific gravity and 0.2 per cent acetic acid.

After ten days in the suspender liquor the hides were removed and laid in another clean pit with 50 kilograms of half-used tan bark and sufficient tan liquor of specific gravity 1.006 to cover the hides. On the fourth day they were handled, and 50 kilograms of fresh bark were added. On the ninth day they were again handled, with an addition of 100 kilograms of fresh tan bark. On the twenty-fifth day they were again handled, with an addition of 130 kilograms of fresh bark; on the forty-fifth day with 210 kilograms, and on the sixty-fourth day with 162 kilograms. The specific gravity of the liquors was taken after each handling.

TABLE XXIII.—*Specific gravity of handled liquors.*

Handling No.	Specific gravity of tan liquor.
1	1.006
2	1.006
3	1.007
4	1.012
5	1.017
6	1.020
7	1.022

While in the suspenders and during the first forty-five days in the laying pit the rate of tannage was rapid. Thereafter it decreased markedly, as is shown in Table XXIV.

The rate of tannage of the carabao hide is noticeably slower than that of the cattle hides on account of its thickness. Such thick hides should consequently always be tanned separately.

[7] The only advisable changes in the Filipino method of liming would be to use from one to three changes of lime liquor and to keep the lime pit clean.

TABLE XXIV.—*Analysis of leather samples taken at different times during tannage, after the twenty-fifth day in the laying pit.*

Day.	Kind of hide.	Moisture.	Parts per 100 of H_2O free material.	
			Hide substance.	Tanning matters and ash.
		Per cent.		
Twenty-fifth	Cattle	17.3	58.7	41.3
Forty-fifth	do	16.9	51.0	49.0
Sixty-fourth	do	14.5	50.8	[a]49.2
Seventy-second	do	14.1	50.1	49.9
Do	Carabao	14.2	53.1	46.9

[a] The owner of the tannery at this point unfortunately added 5 fresh pelts to the pit, thereby reducing the strength of the tan liquor and the degree of tannage.

The increase in strength of the tan liquors, as indicated in Table XXIV, was by no means as rapid as was to be desired. However, as no means were available for grinding the bark, it was not feasible to avoid this objectionable feature. In addition, the process was considerably disturbed by the real or fancied necessities of the owner, who used tan liquor from the layer pit for other hides.

On the seventy-second day the goods were taken from the pit, piled upon a beam to drain, brushed, wiped, and lightly oiled on the grain. When half-dried under the shed, where they hang from one to five days according to weather conditions, they were laid in a pile to temper. This allows the moisture to distribute itself equally throughout the hides. They were then struck out with a striking pin to smooth and flatten the grain and were hung under the shed further to dry. A second striking followed. They were then rolled with a smooth, hardwood roller provided with a suitable carriage and properly weighted, first with a light weight and a slightly moist grain, and then with a heavy weight and a nearly dry grain. After being rolled, the goods were dried rapidly with free circulation of air and finally polished with a brush by hand.

The hides so obtained were free from all of the principal defects of the native leather. They displayed no odor nor evidence of putrefaction at any point. The loss of hide substance was much smaller and the degree of tannage much higher, as indicated by Table XXV, which shows the weight of the native leather and that produced by the improved process.

TABLE XXV.—*Weights of tanned hides.*

Weights of Filipino tanned hides.		Weights of leather from hides tanned in this experiment.[a]	
Australian cattle leather.	Chinese cattle leather.	Australian cattle leather.	Chinese cattle leather.
Kilo.	*Kilo.*	*Kilo.*	*Kilo.*
11.5	9.0	11.5	13.0
10.0	10.0	17.0	11.0
12.5	9.0	16.5	13.0
11.0	10.5	----------	14.0
10.5	9.0	----------	12.0
12.0	10.0	----------	20.0
10.5	9.0	----------	----------
13.0	10.0	----------	----------

[a] These hides are arranged in the same order as in the list of raw hides above in Table XXI.

The average weight of hides tanned by the improved process is approximately 32 per cent greater than that of those ordinarily produced. In other words, the Filipino tanner obtains about 3 kilograms of leather from 6 kilograms of green pelt, while by the improved process this yield of leather is increased to about 4 kilograms of higher grade product. Table XXVI shows the degree of tannage in native leathers as compared with those produced by the improved process.

TABLE XXVI.—*Chemical analysis of leather.*

	Moisture.	Parts per 100 of water-free material.	
		Hide substance.	Tanning matters and ash.
	Per cent.		
Improved product	14.1	50.1	49.9
Filipino product	16.5	61.4	38.6
Do	16.3	62.9	37.1

The color and grain of the hides produced by the improved process, while not perfect, were entirely satisfactory for local market conditions, and the actual increase in the value of the goods by these improvements far exceeded the small increased cost of putting them into effect. Local tanners were alarmed by the large quantities of tan bark which were added to the laying pit. It was difficult for them to realize that no tannin is wasted,

but that the use of old tan liquor, suitably diluted, is to be preferred for fresh hides, so that the entire excess of tannin is eventually utilized. The only actual increase in cost lies in the added labor in finishing the leather. For this expenditure the tanner will be amply repaid. Finally, the practice of chopping bark by hand cannot be too severely condemned as wasteful of tanning material and labor alike. A mill for grinding the bark would repay its entire cost in a few weeks of operation.

An experiment with ten hides was carried out substantially as above outlined, except that mangrove bark was used exclusively in the layer pits after lying in suspender liquor of camanchile. The resulting leather was orange brown, which is not objectionable. The texture was firmer than that of camanchile leather. The partial substitution of mangrove for camanchile is to be recommended as rapidly as the local leather buyers can be induced to accept slightly darker colored goods.

SUMMARY

1. The tanning industry in the Philippine Islands amounts to about 1,800,000 pesos per annum and can be greatly extended.

2. It has been shown that improvements can be put into effect in a Filipino tannery without modification of the equipment and with little increase in expense, which will yield about 32 per cent more leather of a higher grade than that now produced. Leather produced by the improved process is firm, of a satisfactory color and grain, and free from the disagreeable odor or evidence of putrefaction and other principal defects of native leather.

3. A great economy in both labor and material can be effected in the Filipino process by grinding the tan bark in a mill instead of chopping it by hand. The tanning materials never become satisfactorily extracted from chopped bark, and the resulting waste is very great.

4. Good, moderately colored leathers can be produced by combining camanchile and mangrove at a considerably decreased cost.

ILLUSTRATIONS

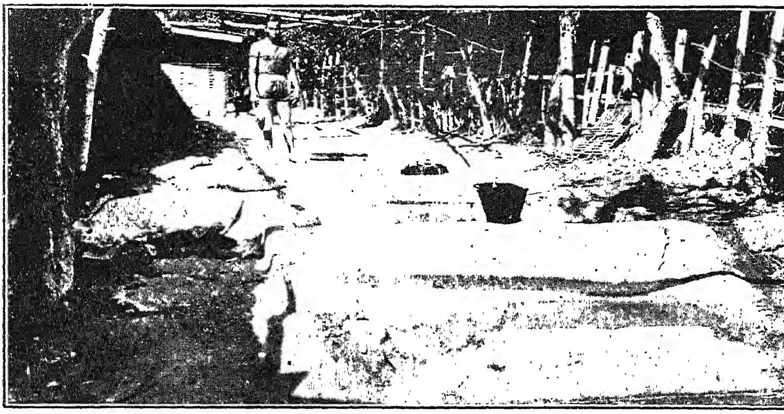


Fig. 1. Liming pits.

Fig. 2. Chopping tan bark.

Fig. 3. Tanning vats.

PLATE I.

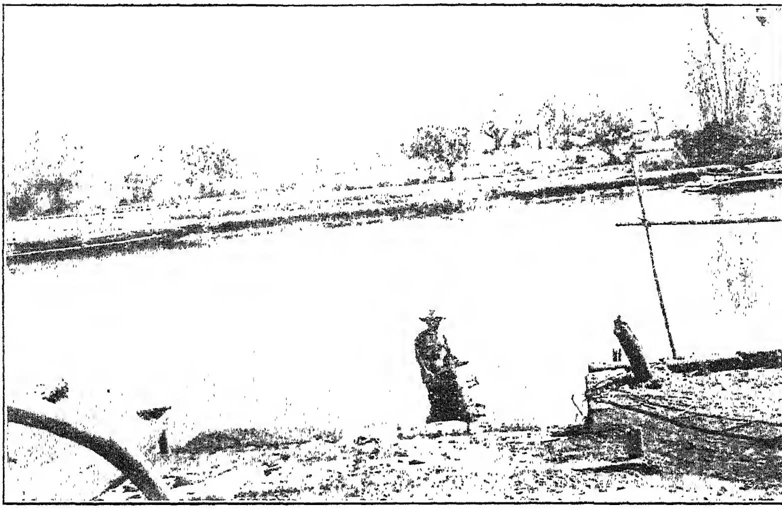


Fig. 1. Dehairing and fleshing at the river.

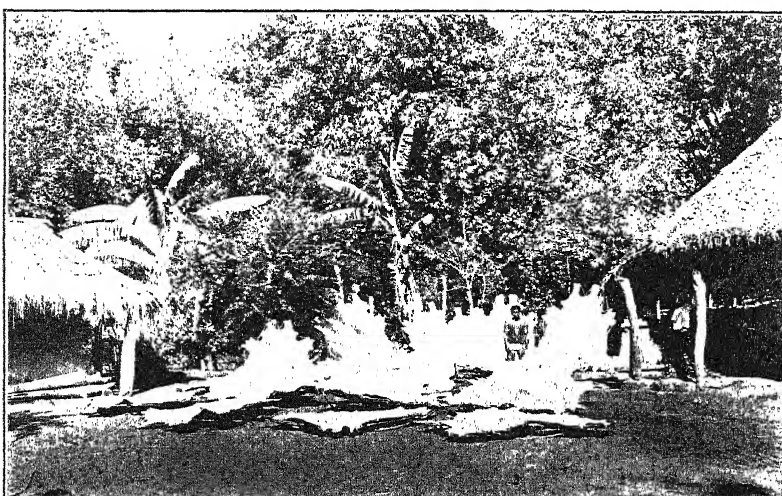


Fig. 2. Drying finished leather.

PLATE II.

SALT INDUSTRY AND RESOURCES OF THE PHILIPPINE ISLANDS [1]

By ALVIN J. COX and T. DAR JUAN

(From the Laboratory of General, Inorganic, and Physical Chemistry, Bureau of Science, Manila, P. I.)

SEVENTEEN PLATES AND 5 TEXT FIGURES

The beginning of the salt industry in the Philippines is obscure. As long as the Islands have been inhabited it is probable that every family along the sea border was its own salt maker. The salt was probably largely obtained by boiling and was an inferior article, as no method was adopted to separate the lime, the salts of the mother liquor, and other impurities. It is impossible to determine just when the first attempt at commercial salt making was made in the Archipelago. Reference is made to it as an ocupation as early as 1583.

Miguel de Loarca in that year wrote of Macagua Island as follows:

> The people are poor and wretched possessing nothing but salt and fish.[2]

Of Lutuya Islets he said, "The chief occupation in all of these islets is making salt and mats," and of Similara Island and the small islands toward Mindoro, "All the people of these islets gather a very scanty harvest; they make salt and are traders." [3]

In 1637, in connection with the commerce of the Orient, which the Dutch carried on with Batan, mention is made of the profit to the island from salt.[4]

In accounts of the successful attack of the Spaniards against the Moro pirates and on Jolo in 1731 we read that the conquerors also ravaged Talobo and Capual Islands and destroyed the salt works there from which the Moros derived much wealth.[5]

In 1687, in a narrative of the Augustinians in the Philippines, Diaz [6] writes of the unprecedented rains which ruined the crops and caused a great scarcity of provisions. He said:

> it was impossible to work the salt-beds, the price of salt rose so high

[1] Received for publication February 10, 1915.

[2] Blair and Robertson, The Philippine Islands. The Arthur H. Clark Company, Cleveland (1903), 5, 53.

[3] Ibid. (1903), 5, 73.

[4] Ibid. (1905), 27, 93.

[5] Ibid. (1907), 46, 39.

[6] Ibid. (1906), 42, 258.

that it came to be worth twelve pesos[7] for half a fanega [½ (55.501 liters)], although its ordinary price was two or three reals [25 to 37.5 centavos]—and some years even less, depending on the (height of the) water and on the heat of the sun, on which conditions this so necessary industry depends.

These and other letters tell of the production of salt at an early date in many parts of the Islands. During the following years mention is made by many writers of the barter of salt and other articles of food on the one hand, and gold on the other, between those who lived along the coast and the inhabitants of the mountains.

All processes for salt making fall into three groups, depending on the character of the heat employed and the manner of its application: (1) Use of solar heat, or solar salt manufacture; (2) direct artificial heat, or kettle and pan processes; (3) steam heat, or grainer methods.[8] The majority of the plants in the Philippine Islands belong to the first group; there are a few in the second, and none in the last group.

USE OF SOLAR HEAT IN DIFFERENT PROCESSES

In warm climates, as upon the shores of the Mediterranean, the coast of California and Mexico, the entire Pacific coast of South America, the islands of the West Indies, Southern Australia, and the whole coast line of tropical Asia, including China and Japan, sodium chloride is obtained by the evaporation of sea water in the shallow lagoons or in shallow basins or pools, constructed upon the seashore and exposed to the sun's rays.

France is one of the most important sea-salt-producing countries of Europe. The total area covered by the salt works is about 19,000 hectares, in 12 departments—7 on the Mediterranean and 5 on the Atlantic coast. In this industry some 8,000 laborers are employed for several months every year.[9]

Portugal, Spain, and Italy are also among the chief sea-salt-producing countries of Europe.

Italy is the cradle of the saltern industry. Pliny relates that Ancus Martius, the fourth of the early kings of Rome, who reigned from 640 to 616 before Christ, was the first who had sea water led into closed basins to evaporate for salt. Later many such salterns were established, so that even in very early times the manufacture of sea salt was an important industry. An interesting relic of this is the Via Salaria—the salt road—one

[7] One peso Philippine currency equals 100 centavos, equals 50 cents United States currency.

[8] *7th Annual Rept. U. S. Geol. Survey* (1886), 505.

[9] Furer, Salzbergbau (1900), 269; *Bull. La. Geol. Surv.* (1907), 7, 158.

of the oldest of Roman roads, which was built to accommodate the salt trade.[10]

China is one of the oldest salt-producing countries of the Orient. In former times the salt trade in China was so highly esteemed that at the annual opening of the salt works princes were present in person and took an active interest in the first salt boiling.[11]

In many of these countries the production of salt is a state monopoly, or is under government control. The salterns, or salt farms, are either leased to private companies, or are administered directly by the officials of the government. A good example of this is China, where taxation of salt commenced as far back as the seventh century before Christ. It is said that the great Emperor Yu, 2205 to 2197 before Christ, ordered Chingchou Province to supply the court, among other things, with salt. During the Chow dynasty, 1122 to 249 before Christ, officers were appointed for the administration of salt matters. At the present time the revenue derived from salt is the Chinese Government security for the reorganization loan of 25,000,000 pounds sterling.[12]

Since American occupation all restrictions on the manufacture of salt in the Philippines have been withdrawn.

Solar evaporation must be carried on in general where it is hot and where evaporation greatly exceeds the rainfall—that is, where there is a pronounced dry season. Fig. 1 shows that there are two definite and different types of rainfall in the Philippines. The eastern half of the Archipelago has a rainfall more or less equitably distributed throughout the year; hence the principal salt works are confined to the western portion of the Islands, where there is a definite dry season.[13]

The degree of difference in the two types is shown in figs. 2 and 3, where the mean of the values [14] for the two groups is graphically represented. The normal evaporation from 1885 to 1907 for Manila is also shown in fig. 4.

[10] *Bull. La. Geol. Surv.* (1907), 7, 168.

[11] *Far East. Rev.* (1912), 9, 295.

[12] Ibid. (1912), 9, 295.

[13] The differentiation of rainfall into the eastern and western types may not be complete; for example, there is but one weather station in Mindoro, and while it and probably the remainder of the low portions of the island fall in with the western type, it is believed that the rainfall in the high mountains is very heavy, due to the fact that the narrow neck of Luzon in Tayabas allows the rain clouds to pass over and precipitation to take place in the high altitudes of Mindoro.

[14] Cox, Alvin J., *This Journal, Sec. A* (1911), 6, 288–91.

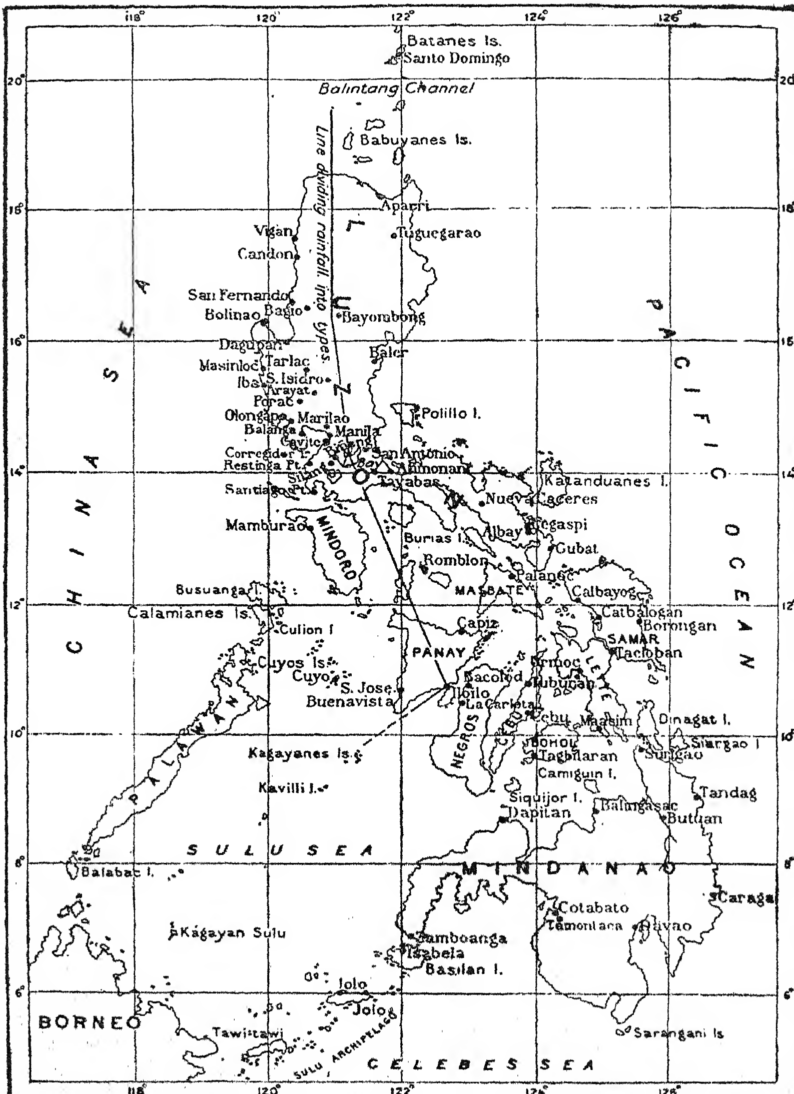


FIG. 1. Map showing two definite types of rainfall in the Philippines.

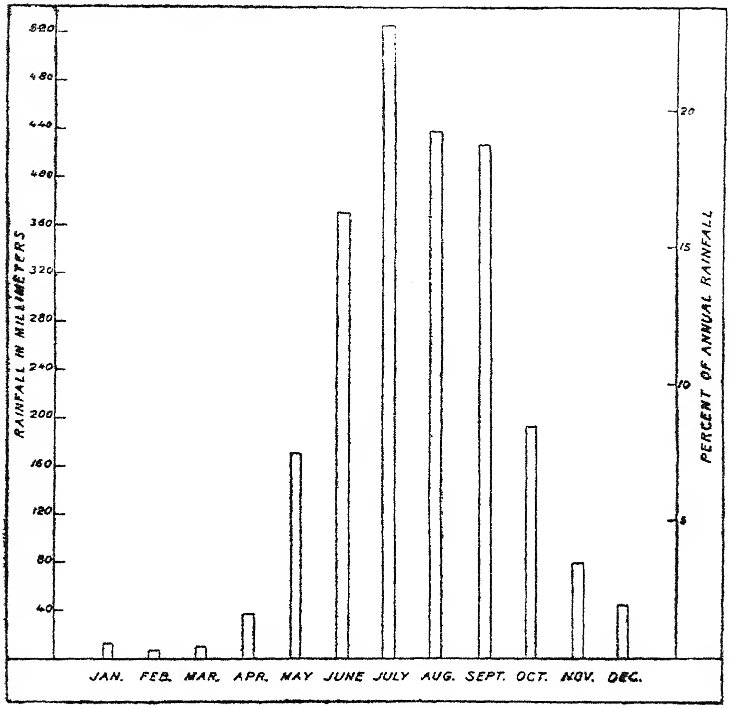


FIG. 2. Mean rainfall in the western portion of the Philippine Archipelago.

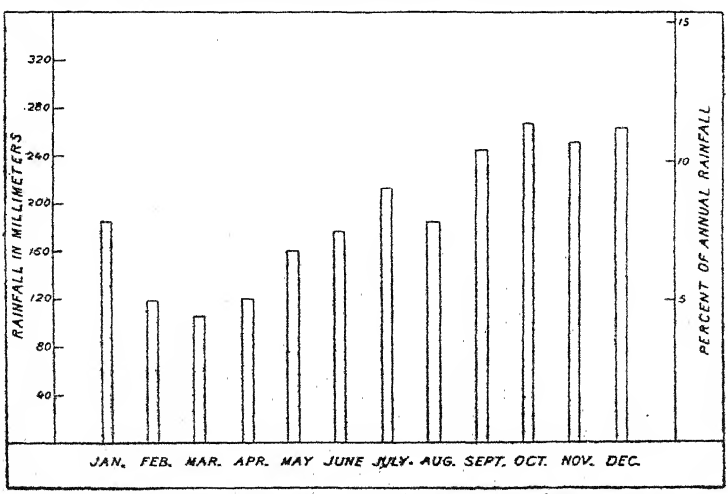


FIG. 3. Mean rainfall in the eastern portion of the Philippine Archipelago.

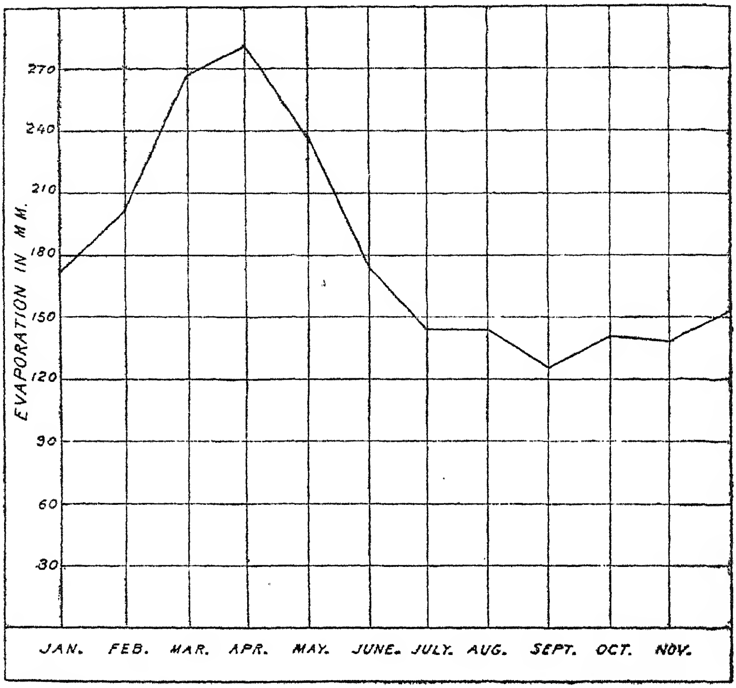


FIG. 4. Normal evaporation 1885-1907, Manila.

In view of the diminution in the rainfall and the high evaporation one would anticipate salt works using solar heat in the western half of the Archipelago to operate from December or January to April or May, which accords with the actual case.

DIFFERENT METHODS USED FOR THE MANUFACTURE OF SALT

A method commonly known in the Provinces of Batangas, Bulacan, Cavite, and Rizal by the name of *iras Tagalog* (native method) has been used in the Philippines as long as any of those now employed in the industry can remember and is probably the original method used in these Islands.

The process is as follows: Large areas of sandy land along the coast, approximately at the level of high tide, are cleared of vegetation and cleaned. The surface of the prepared land (*abuhan*) is loosened, and water from canals (*angkaw*), through which it is led in from the sea or from the estero, is sprinkled over the area where it rapidly evaporates. This process is repeated about four times a day for three consecutive days, until

a quantity of salt has accumulated on the surface. On the fourth or the fifth day the loose earth, together with the salt, is scraped into heaps and collected into leaching vats, called *hornohan* (from the Spanish "horno," which literally means "oven), where it is leached with sea water or weak brine until most of the salt has been extracted and a concentration of about 10 per cent of salt by weight is obtained. In many plants using the Filipino method the leaching vats are located at a point intermediate between the canals, where sea water is available. In this case the sea water is conveyed to the vats by means of an inclined bamboo pipe, the lower end of which rests upon an open-work bamboo basket, or other device, to prevent violent impact of the water, and the upper and larger end of which carries an earthenware jar (*pilon*) or galvanized-iron funnel to receive the water.

TABLE I.—*Mechanical analyses of soil used for evaporating salt water.*

[Numbers give percentages.]

Classification.	Sample from—		
	Las Piñas.	Bacoor.	Aplaya, Batangas.
Detritus, 2 to 1 mm	5.1	26.3	15.6
Fine earth, water-free basis:			
Coarse sand, 1 to 0.5 mm	1.8	11.1	7.0
Medium sand, 0.5 to 0.25 mm	5.2	17.4	22.9
Fine sand, 0.25 to 0.10 mm	9.5	12.6	30.4
Very fine sand, 0.10 to 0.05 mm	16.7	10.6	12.2
Silt, 0.05 to 0.01 mm	19.8	3.4	7.5
Fine silt, 0.01 to 0.002 mm	29.6	35.8	12.0
Clay (and salt) <0.002 mm	17.4	9.1	8.0

In the Philippines there are many salt-water shrubs and trees which when green have a specific gravity greater than that of water. In Rizal, Cavite, and Bulacan Provinces it is a common practice among Filipinos to pluck twigs of the plant known by the name of *culase* (*Lumnitzera racemosa* Willd.), which grows in the marshes near salt farms and along the levees of the evaporation reservoirs, strip them of their leaves, and throw them in the brine to test its strength. If they sink, the brine is not yet strong enough, but when they float, the brine is sufficiently concentrated to be transferred to the crystallizing ponds, called *banigan*. The specific gravity of the culase twigs of the size used has been determined by one of us to be about 1.085, or equivalent to 11.5 per cent by weight of salt. The culase varies from 1.070 to 1.096, depending on whether it is smaller

or larger than the size used by the Filipinos in determining the strength of the brine. There are very few Filipinos who use a specific gravity spindle or a salometer to determine the strength of the brine.

The leaching vat commonly used in Rizal and Cavite Provinces consists of a circular dike about 50 centimeters high and 4 meters in diameter, which is built on the ground. The bottom is covered with a layer of palm leaves, usually nipa, and rice husks, which filter the mud from the brine. By means of bamboo piping the filtered brine is drawn off through the dike into a shallow cement, earthenware (pilon), or clay-lined well. Dilute brine is dipped back into a leach, and the operation is repeated, until it becomes strong, when it is transferred to shallow crystallizing ponds.

After the leached mud has hardened slightly, it is marked off into squares. While the leaching is in progress, another layer of loose earth is being impregnated. This is scraped into heaps about the leach, while the squares of leached mud are drying. When the blocks have sufficiently hardened, they are thrown from the leach back on to the field. After the second crop of salty earth has been scraped into the leach, the clods are pulverized and carefully spread out again to be impregnated.

The crystallizing ponds are floored with smooth, broken pottery (tinajas or pilones) set in lime mortar to retard seepage and to prevent the admixture of sand with salt. The ponds are surrounded with bamboo fences covered with nipa or cogon grass in order to prevent the prevailing wind from blowing dust into them and the floating crystals from congregating on the leeward side. As the crystallizing ponds require more liquid, more and more of the strongest brine is added. It is poured through a straw-filled, open-work basket filter to remove rice husks, which may have gotten in from the leach, and especially to prevent disturbance of the bottom of the pond. When the brine is sufficiently concentrated to deposit salt, every day after sundown, when the temperature has fallen, to give the maximum crystallization, the crystals are raked into heaps at the side of the vats, gathered into baskets to drain, and finally conveyed into warehouses.

MODIFICATIONS OF IRAS TAGALOG METHOD

The iras Tagalog method is more or less modified in other parts of the Archipelago, but the principle of the process remains the same. In Antique, Cebu, Iloilo, Negros, and Palawan Provinces beds of bamboo split in half serve as crystallizing ponds.

In certain localities as, for example, Pangasinan Province low land below the tide level is used for evaporating salt water. In this case the depression is leveled, inclosed by dikes, and filled with tide water, which is evaporated by the sun's heat; when the water has disappeared, the surface crust is gathered up and leached as described previously. In this locality the leaching apparatus is frequently a small banca, in which a hole has been made at the bottom and covered with layers of straw and rice husk. The concentration of the brine is determined by throwing in it twigs of the guava tree. If they float, the brine contains the required amount of salt to be boiled, but if they sink, it is not yet sufficiently concentrated to be transferred to *cauas* (kettles). It is saved for leaching fresh amounts of salt-impregnated earth. The specific gravity of the first leachings, or concentrated brine, called *irna,* as determined by means of guava twigs, varies from 1.185 to 1.196.

People from Ambos Camarines, Albay, Bohol, Batanes, Capiz, Cagayan, Ilocos Norte, Ilocos Sur, Leyte, Misamis, Nueva Vizcaya, Pangasinan, Surigao, Sorsogon, Samar, Union, Zambales, and Mountain Provinces vary the process by evaporating to dryness the brine of the final leachings in cauas, or huge, thick, iron pans or kettles, mounted on rude clay furnaces. Sometimes the process is much less refined. A fire is built on the beach, and sea water is continually sprinkled on it, though not in such quantity as to put out the fire. Finally the fire is allowed to burn out, the ashes are leached, and the evaporation is made by artificial heat as above outlined. The crystals produced by boiling are formed rapidly and are, therefore, not so large, so hard, nor so desirable for packing purposes as those produced by slow evaporation.

In Japan a plan somewhat different from the method just described is employed.[15] The floor of the salt farm is made perfectly level and is covered with an even layer of clay, which is packed down and covered with a thick bed of coarse sand, which is kept loose by frequent raking. The sand is irrigated with sea water, led in through narrow ditches, which is allowed to evaporate. The process is repeated until the sand has become thoroughly impregnated with salt. The sand is then put in filters, sea water is poured on, and the brine which filters through is evaporated in pans over charcoal fires.

It is of interest to note the great similarity of the processes used in the Philippines for the manufacture of salt to the

[15] *Bull. La. Geol. Sur.* (1907), 7, 195.

processes used in China, where they either boil the brine or else evaporate it in the sun, according to a recent article,[16] from which we quote the following:

on the very first day of opening operations in the salt-works the seashore is cleared of weeds, and a beginning is made by digging out the upper layer of earth and breaking it up; this earth when broken up is turned over and over with bamboo poles until it is fine and smooth. Then sea-water is brought from ingenious receptacles, which are filled with water at high tide, and the earth is moistened with it, as with light rain, equally and thoroughly. Towards evening the earth is shovelled to one side, and a long line of mounds is formed of it, in order to protect it from rain during the night. On the following day the procedure is the same as on the previous day, except that the earth is carried to some particular spot for safety. In fine weather it is taken out again from time to time, and dried on the salt-grounds.

As soon as the earth has been thoroughly prepared, i. e., is completely impregnated with salt particles, the workers take it to the ovens. These ovens [not a real oven but a leaching vat], which are shaped like chests, 9 ft. long, 2 ft. broad, and 3 ft. deep, are called Lu; near each a well 8 ft. deep is dug. The floor of the oven is strewn with rotten wood; above this are fine bamboos; on them is a layer of brushwood, and above all is a layer of ashes of plants. The prepared earth is shot upon this, beaten hard and covered with rice straw. On this is poured sea-water, which finds its way through all the inner layers, and flows into the well as brine. Each oven in 24 hours gives more than 20 *tan* (60 pud) of pure brine, which is drawn out of the well and taken to the boiling oven to be boiled * * *. Each boiling begins at 11 p. m. and continues until 10 o'clock on the following morning * * *. It appears in three qualities and colours: white, dark and yellow: the white is the best, the dark not so good, and the yellow much inferior and of a bitter taste.

The second method * * * is distinct from the first, in that the brine is not boiled, but poured into peculiar paved tanks, and left there to the sun and wind. For complete evaporation two days in summer, and 3–4 at other times are sufficient, and indeed the N. W. wind is quite as favorable to this operation as are the sun's rays; on the other hand, with unfavorable winds, and in rainy weather, no salt is taken.

Another method in use in the Philippines, introduced in recent years by the Chinese, utilizes most of the lower areas—that is, the vast stretches of overflowed tide lands, or salt marshes, at the head of the bays or along the coast line. The land best suited is that flush with an ordinary tide, so that it may be covered from 30 to 50 centimeters deep by a high tide. The land, having been cleared of vegetation and débris, is first leveled and then diked with levees a meter or more high. It is then partitioned off into reservoirs, shallow evaporation lakes, or stock ponds of different sizes, depending on the size of the plant itself, for receiving, settling, and evaporating the sea

[16] *Far East. Rev.* (1912), 9, 303.

water and precipitating the silica, oxide of iron, calcium carbonate, and calcium sulphate.

The reservoir in which the first evaporation takes place is usually a fish pond; in addition to this, there are in most salt plants three rows of shallow concentration reservoirs, seldom less than four in a series, and often six or seven. The brine is drawn from one reservoir to another as it strengthens and decreases in volume by evaporation, and new water is in turn admitted from the bay. Beyond the reservoirs crystallizing ponds are constructed in the manner already described. Seepage from the crystallizing ponds is collected in ditches, which carry it to a well, from which it is baled out with a bamboo sweep into another ditch, which returns it to the evaporation reservoirs containing the strongest brine. When the crystallizing ponds are higher than the evaporation reservoirs the brine is dipped up by hand; sometimes it is poured into an apparatus similar to that used in filling the leaching vats, allowed to run through a straw filter, and thus transferred to the crystallizing ponds. When land above tide level is employed for the greater part of the manufacturing plant, the water is elevated with a bamboo sweep. In the ideal plant the whole process is by gravity.

Water transportation connects most or all of the salt works with deep water, from where connection can be made via navigable streams with many of the inlands provinces.

The working season for the plants along Manila Bay varies somewhat from year to year, but usually begins in December and continues until about May—a period of approximately one hundred fifty days.

The product obtained by the process above described is coarse and not usually of the best quality, as it contains magnesium salts and other impurities. The brine thus treated will not give a product containing much over 93 to 94 per cent sodium chloride. If, however, the mother liquor containing the bulk of impurities—that is, most of the magnesium and sodium sulphates and practically all the magnesium and calcium chlorides—is removed from time to time, a much higher grade of salt may be produced.

The magnesia and lime content of Philippine salt are shown in Table II.

The first concentration or evaporation reservoirs are preceded by a fish pond, not shown in figure 5, specific gravity 1.025, which is supplied at its intake with water having a specific gravity of 1.024. In all of the Philippine plants the brine was transferred from the evaporation reservoirs to the crystallizing

TABLE II.—*Showing the magnesia and lime content of Philippine salt.*

[Numbers give percentages.]

Source.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Remarks.
Parañaque (1) (1911)	0.96	0.85	Prepared from estero water. Filipino method.
Parañaque (2) (1911)	1.24	0.84	Prepared from estero water. Chinese method.
Malabon (1911)	1.66	1.93	Do.
Obando (1911)	0.79	1.81	Do.
Obando (1) (1913)	0.33	0.33	Do.
Obando (3) (1913)	0.70	0.45	Do.
Obando (4) (1913)	0.78	0.39	Do.
Obando (5) (1912)	0.34	0.73	Do.
Obando (6) (1912)	0.47	0.67	Do.
Ahinan	6.14	trace	Salt spring.
Ahin	4.03	1.43	Do.
Bayombong (5)	trace	0.25	Do.
Bayombong (6)	0.55	trace	Do.
Bayombong (7)	1.74	0.50	Do.

pond at a density never greatly exceeding 1.13, the concentration at which gypsum begins to deposit, which is too soon. Fig. 5 gives the concentrations of the brine of a plant in actual operation. The effect is readily noticeable on the composition of the product, which contains a high percentage of lime. The bitter salts are not removed from many of the crystallizing ponds, and the effect is evident in the high magnesia content of the salt. The lower magnesia content of the Parañaque sample given in Table II is due to its being an early crop before the bitterns had become greatly concentrated.

The salt produced by the old Filipino method has acquired a reputation for its superior qualities for curing fish. Many a Filipino will say that it takes more of the salt produced by the new, or Chinese method, to preserve a given weight of fish. In the old process the water is evaporated to dryness, and gypsum, which is not readily soluble, is largely eliminated, for only a small amount of it is redissolved in the leaches. In this way the separation is more complete than is now common practice in the new method, where the brine is transferred to crystallizing ponds too soon. By the old method, particularly, the salt was usually retained in warehouses for some time. With the new method salt is produced in large quantity and is frequently sold directly after draining and before the pile has weathered and the hygroscopic salts have been washed out by the absorption of moisture from the air. These differences

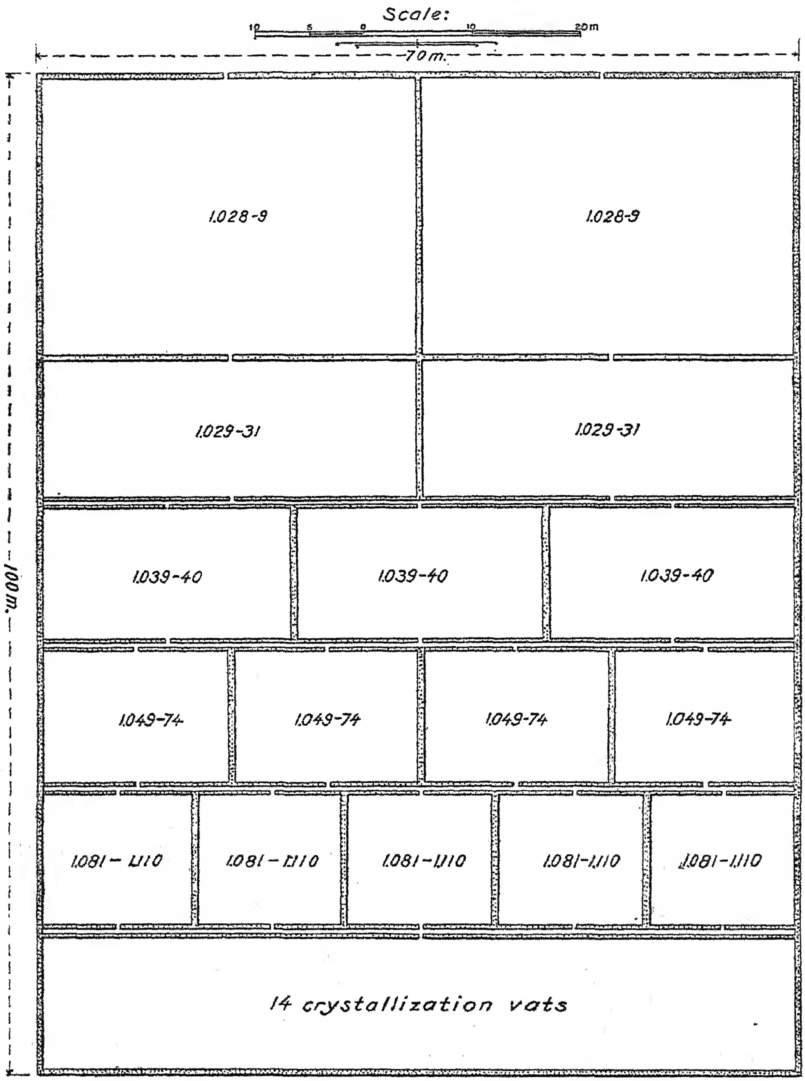


FIG. 5. A general diagram showing specific gravity of brine in the different concentration reservoirs of plants in actual operation.

are the only ones which exist. With proper manipulation the salt produced by the Chinese method will have as high a percentage of purity and a whiter color than that produced by the Filipino method.

So far as we have been able to determine, the area devoted to crystallizing ponds in plants using the process introduced by the Chinese is one sixth to one fifth (excluding the fish pond), or even more, of the area covered by the evaporation reservoir. However, taking into consideration the fact that for the more complete separation of the less soluble salts the volume of the brine should be reduced more than is done in common practice, the above ratio is much larger than is necessary.

In order to carry on the process of evaporation in the most efficient way, the following facts should be given due consideration:

1. The rate of evaporation for any solution decreases as the concentration is increased. Accordingly, in order to counteract retarded evaporation in the various steps of the process a slightly greater than proportional surface area is needed in succeeding concentration reservoirs. This fact is almost negligible except in fairly concentrated solutions and is probably more than compensated by seepage. The latter varies, depending on the nature of the soil, and the average should be determined and taken into consideration in the construction of a plant.

2. The capacity and surface area of the evaporation reservoirs of any row should be proportional to the quantity of brine delivered from the reservoirs of the preceding row.

3. The specific gravity of the brine should be controlled in such a way that each row of evaporation reservoirs should receive and deliver a brine of definite specific gravity.

4. The area occupied by the crystallization vats should be as small as possible to accommodate the brine concentrated in the evaporation reservoirs, for in that way as much salt can be obtained with less labor.

If we neglect the effect of the precipitation of the less soluble salts (calcium sulphate, calcium and magnesium carbonates, oxides of iron and alumina, etc.) on the density of the brine during the process of concentration, we can establish for practical purposes the principle that the density of the brine varies inversely proportional to its volume and for a given depth inversely proportional to the superficial area.[17]

The salt supply of Mountain Province for the greater part comes from Cervantes and is sold to the people at exorbibant prices. The people of Mountain Province also produce a very

[17] On this basis the approximate volume of the brine at any given density may be determined and the corresponding size of the concentration reservoir to contain it may be calculated.

small amount of a poor grade of salt by evaporating water from the carbonated brackish springs at Mayinit, Bontoc; Tukukan, Ahin, and Bungubungna, Ifugao; and Salinas, Nueva Vizcaya.

TABLE III.—*Chemical analysis of some waters used for the preparation of salt.*

[Numbers give parts per thousand.]

Source.	Iron and aluminium oxide (R_2O_3).	Calcium oxide (CaO).	Magnesium oxide (MgO).	Potasium oxide (K_2O).	Potassium calculated as potassium chloride (KCl).	Sodium oxide (Na_2O).
Ahinan Spring, west flow of Guadalupe crater	trace	4.022	0.049	0.085	0.135	5.488
Tukukan Spring	0.003	0.333	0.066	0.919	1.454	2.334
Ahin Spring	0.027	0.618	0.255	1.242	1.965	5.021
Mayinit hot spring	0.088	0.128	0.001	0.023	0.036	0.457
Balatok Spring	0.085	0.868	0.007	1.580	2.500	8.688
Malabon estero	0.036	0.854	2.078	0.717	1.134	14.15
Parañaque estero	0.028	0.654	1.025	0.764	1.209	13.18

Source.	Sodium calculated as sodium chloride (NaCl).	Silica (SiO_2).	Chlorine (Cl).	Sulphuric acid radical (SO_4).	Carbonic acid radical (CO_3).	Bromine (Br).
Ahinan Spring, west flow of Guadalupe crater	10.340	0.023	11.09	8.468	----------	----------
Tukukan Spring	4.397	0.103	3.33	0.035	----------	----------
Ahin Spring	9.461	0.106	6.89	0.151	----------	----------
Mayinit hot spring	0.861	0.195	0.75	0.295	0.208	----------
Balatoc Spring	16.370	0.317	11.59	0.236	----------	----------
Malabon estero	26.660	0.024	20.96	2.626	----------	0.185
Parañaque estero	24.830	0.008	18.84	2.780	----------	0.243

It is not known just when the salt springs were discovered. The supply of brine varies in quantity and in strength. In some places it is not large and of little or no present economic value, but it could probably be developed. The result of the abnormal price is that in certain places at certain times of the year the entire supply of brine is used by operators who take turns at the spring.

Most of the plants now used are very much like those described in ancient history. They consist of a few cauas, obtained from the Ilocanos, mounted on crude furnaces built of stone and clay. There are no furnaces with a large number of kettles, and often there is only one kettle to a furnace. At present there is little attention paid to the economy of heat, although eventually the

success or failure of the process will depend on whether or not there is economical application and thorough utilization. The salt obtained in this way is very inferior, as no method is adopted to separate the salt from the mother liquor or other impurities, either organic or inorganic. In this crude way about 12 kilograms per day per kettle are manufactured. By the old solar method the average daily production per laborer varies from 14 to 85 kilograms of salt, depending on the locality and the refinement of the process, while the average production for the new process is about 200 kilograms of salt per laborer per day.

At Mayinit the salt water is hot, contains 0.3 per cent by weight of salt, and flows from the spring in several shallow streams. Salt houses are built over carefully leveled plots of clayey soil, upon which water from the stream is led. There are more than 100 such houses, usually about 4 meters wide and from 4 to 8 meters long, with grass-covered roofs extending to the earth. The ground space of the salt house is paved with stones from 10 to 15 centimeters in diameter. The hot water is allowed to spread out and pass among the bases of these stones; thence it is carried up on the stones by capillarity and evaporates fairly rapidly from the exposed hot surfaces, leaving a thin crust of salt.

About once each month the salt is gathered by washing the encrustation from the stones into a large wooden trough, called a *ko-long-ko*. Each stone is thoroughly washed and then replaced in the pavement. The saturated brine is preserved until sufficient is gathered for evaporation, when it is boiled as above described. The product is pressed into cakes and placed upon bits of broken earthenware and is baked either in the fire or in the sun. The dried salt contains only about 87 per cent sodium chloride.[18]

The flow of the springs at Tukukan and at Ahin is probably about 500 liters per hour each and contains 0.6 and 1.2 per cent of salt, respectively. The Tukukan spring is rather inaccessible, but that at Ahin is on the bank of the river down which is floated the necessary wood for the furnaces, from the pine forests above. The Ahin spring comes from a crevice in the solid rock and could probably be developed.

In July, 1910, there were a dozen kettles in operation, which consumed the entire output of the spring at Bungubungna.

At Salinas the sight of the two springs is wonderful aside from the salt-making operations. The brine comes from the springs

[18] Jenks, A. E., *Pub. P. I. Eth. Sur.* (1905), 1, 145–7.

in the side of the mountain highly charged with carbon dioxide, under which condition it carries, besides 3.2 per cent of salt, large quantities of lime and some iron in solution. On reaching the surface, where the pressure is released, the carbonate of calcium is deposited, and in this way the springs have built up huge mounts of mineral deposits.

A portion of the water is collected and carried nearly 2 kilometers through troughs made of split bamboo. These are very rapidly coated with sulphate and carbonate of calcium in that portion of the line nearest the spring, the amount of coating decreasing fairly rapidly with distance. In fact, the objects of carrying the water so far through open troughs are to get rid of the undesirable substances which precipitate before the salt and also in order that firewood may be closer at hand for the boiling.

Hardwood logs are used for fuel and are shoved in from both sides of the furnace, so that the points meet at the center. As the points burn off, the logs are shoved in farther. Practically the only cost of producing salt here is the cost of getting out the wood. About 70 pans were in operation in June, 1911.

Only a small part of the water which is at present flowing from these springs is utilized, yet it furnishes 125,000 kilograms of salt annually for a population of about 50,000 people. Thus there ought to be an opportunity for doing away with kettles and open pans and starting a modern concentration plant with steam heat.

There is some coal in Nueva Ecija, and coal is as good as fuel and is even better for salt vacuum pan or grainer units than wood. In general, when kettles and open pans are used, they are placed over a long combustion chamber in direct contact with the flames from the furnace. Steam heat is more frequently used when vacuum pans are employed. The grainer process requires steam heat exclusively. The steam is carried through pipes submerged in the brine. The temperature is varied by varying the pressure, so as to obtain salt having the desired grain. This process is now much more generally used in the United States than any other. The removal of the gypsum depends upon a quiet, regular boil of the liquid, which cannot be uniformly obtained in all the kettles of a block, and therefore the quality of the salt is variable. Furthermore the heat causes the calcium sulphate to form a scale, which clings to the kettle and thus reduces the efficiency. The general result is that a better quality of salt is produced, and about 50 per cent more evaporation is

effected by a given quantity of fuel when it is fired under a properly constructed boiler to produce steam for heating purposes than in any other way.

The history of the development of brine in the United States is that the brine is stronger and more plentiful with depth. At East Saginaw, Michigan, brine of 1° was struck at 90 feet (27 meters) and increased until at 636 feet (193 meters) 90° brine was reached.[19] It may be possible that the rock from which the brine springs emanate lies deep, and a mass of rock and earthy matter will have to be penetrated before the source can be reached. Again the brine of the Mountain Province springs is probably diluted by surface seepage and a stronger brine may perhaps be obtained by developing the springs and bringing the brine to the surface undiluted. On the other hand, the salt may have its origin in sands, silts, clays, or shales saturated with salt from sea water during deposition and in which the impregnated salt has been preserved by the overlying strata.

Formerly the Philippines produced practically enough salt for domestic consumption. This is no longer true. The imports of salt into the Philippines have exhibited an almost constant increase since American occupation. The exports of domestic salt have had no influence on the trade, amounting to nothing except in 1907, when there were 4,280 dollars worth exported, of which 3,196 dollars came from the port of Zamboanga and 330 dollars from Manila, presumably the product of Malabon. Salt pays an import of 20 cents per 100 kilograms when crude and 50 cents per 100 kilograms when ground, powdered, or otherwise manufactured, and the fact that in the only year in which the local supply has equaled the demand Zamboanga was able to supply its local needs and to furnish a surplus for exportation seems to argue that the rates imposed are sufficient for the protection of the local industry. In recent years there have been no exportations. It is interesting to note the sources and value of our imported salt.

The principal source of our importations is China, which sends only coarse salt brought in shipments of from 1- to 300-bag lots. This indicates that the local production of salt does not keep pace with the growth of the packing industry. Prior to 1907 there was not so great a demand for salt for packing purposes. By actual count in 1907 there were but five Chinese engaged in the packing of sardines in Tondo, but before the great Tondo

[19] *18th Annual Rept. U. S. Geol. Surv.* (1897), 5, 1304.

TABLE IV.—*Showing source of imported salt.*[a]

[Value in dollars, United States currency.]

Source.	1901	1902	1903	1904	1906	1907
United States						
United Kingdom						
Belgium						
Denmark						
France						
Germany						
Spain						
China						
Singapore						
All other British East Indies						
Japan						
British Australasia						
Total	3,693	8,583	20,985	5,176	1,852	2,321

Source.	1908	1909	1910	1911	1912	1913
United States	216	137	114	2,030	6,026	5,069
United Kingdom	2,322	2,504	4,508	3,061	4,938	3,244
Belgium			4			
Denmark				68		
France		5		41		
Germany	24	29	51	56		
Spain		11	9	6		
China	396	67,557	51,498	54,102	49,187	47
Singapore	38	206	171	1,204	182	216
All other British East Indies		405	95			
Japan				171	816	1
British Australasia	39	238	299	366	142	324
Total	3,035	71,092	56,775	61,105	61,291	8,901

[a] No figures obtainable for 1905. The Philippine Customs reports are issued in dollars U. S. currency.

fire of 1911 there were thirty-six in that section of the city, each using large amounts of coarse salt for the purpose of curing fish.

Considering the increased importation and the import tax of 25 per cent ad valorem, the manufacturers should find a great deal of encouragement and there should be a good margin. If the producer here had to compete with the salt of the United States at an average price of 44 centavos per kilogram, which includes not only the cheap grades of salt, such as the coarse salt made here by solar evaporation, but also the very finest grades of table and dairy salt, which are prepared with great care and expense and which constitute a considerable percentage of the total, it would be more difficult. However, the manufacturer in the Philippines has to compete only with salt produced by the same methods as he himself employs and is protected by the

tariff regulation. As yet the only product in the Philippines has been coarse salt, for there has been sufficient demand from tiendas and packers to consume it entirely as such.

SALT MILLING

So far as we have been able to determine, there have been no attempts at salt milling in the Islands. A short description of this process may not be out of place.

Each mill is constructed with one or more sections containing a drier, several sets of rolls, fans, shaking sieves, etc. The modern plants use rotary driers consisting of two concentric cylinders clamped together and rotating on bearings which support the outer cylinder. The inner cylinder, or steam drum, is about 1 meter in diameter and is fed with live steam. The outer cylinder is about 2 meters in diameter and 15 meters long, through which hot air is blown. The dryer is set at an inclination of about 3 or 4 degrees. The salt is fed into the space between the two cylinders at the upper end, and as the drier revolves the salt slowly travels toward its lower end where it is discharged. It is then carried to the first set of rolls. After passing through these, the crushed material is sent over a shaking sieve, which acts as a separator, allowing the fine stuff to go to the bagging room, while the coarser material is conveyed to a second set of rolls, which are set closer than the first and, therefore, give a finer product. This is again sieved, separated, and crushed in still finer rolls, the process continuing until the material has passed through several sets of rolls of increasing closeness, passing over sieves after each crushing. Salt of various coarseness is produced by the use of sieves of varying mesh which feed into different bins. Fans are placed over the top of each sieve and also in the rolls and driers. These fans take off the very lightest and finest material, and their product is conveyed into a room where it is pressed for cattle feed. As the magnesium and sodium sulphates are considerably lighter than the sodium chloride, the use of these fans takes out much of the sulphates and purifies the salt very appreciably, as demonstrated by analysis.

Few statistics of the salt produced in the Philippines have been kept, and it has been necessary for us to gather ours partly by letter. Some manufacturers returned replies very complete, others very lacking in essential features, though we believe all are fairly satisfactory with regard to output. We have carefully studied the plants in Obando, Malabon, Las Piñas, Parañaque, Bacoor, Kawit, and the principal producing towns of Pangasinan. In many places a suspicion that we were gathering data as a basis for taxation kept the men engaged in the industry from giving information freely. Since there is no basis of comparison, it is impossible to prove a large increase in the local production. Information from municipal presidentes shows that there were 105 municipalities representing 30 provinces where salt is manufactured and that in round numbers 19,000,000

kilograms were produced in 1911, all of which was coarse salt.[20] In reporting the production some operators used the cavan as a unit of measurement, others the *simat*, and others the *curibot* or *babaco*. For the sake of convenience the product has been reduced to kilograms on the basis of 1 cavan equals 49.5 kilograms. Some of the data obtained from municipal presidentes give the results expressed in Tables V and VI.

TABLE V.—*Annual production of salt in the Philippine Islands by solar evaporation.*

Province.	Process used.	Production.
		Kilos.
Antique	Filipino	110,254
Bataan	do	142,560
Batangas	do	1,299,870
Bohol	do	27,353
Bulacan	Filipino and Chinese	71,280
Cavite	do	2,005,312
Cebu	Filipino	482,660
Iloilo	do	943,357
Mindoro	do	49,500
Moro Province	Chinese	991,200
Occidental Negros	Filipino	95,056
Oriental Negros	do	33,896
Palawan	do	34,650
Rizal	Filipino and Chinese	7,055,400

TABLE VI.—*Annual production of salt in the Philippine Islands by artificial heat evaporation.*

	Kilos.
Albay	small amount
Ambos Camarines	27,000
Batangas	([a])
Bohol	([a])
Cagayan	40,830
Capiz	491,280
Ilocos Norte	783,051
Ilocos Sur	1,983,233
Leyte	2,640
Misamis	40,800
Mountain Province	11,400
Nueva Vizcaya	125,000
Pangasinan	1,026,835
Samar	2,817
Sorsogon	9,900
Surigao	4,000
Union	445,585
Zambales	356,181

[a] See Table V.

[20] The total production of salt in the United States in 1909 was 3,825,000,000 kilograms, worth 16,688,000 pesos. The production in the Philippine Islands looks somewhat small; however, it is not so small from the standpoint of the other industries.

The importance of salt production as a Philippine industry, where its rank, with reference to a number of items, is given, is well shown in Table VII.[21]

TABLE VII.—*Comparative table of industries.*

[Numbers indicate rank in comparison with all other Philippine industries.]

	Salt.	Black-smithing.
Number of establishment	[a] 11	[b] 13
Capital invested	[c] 15	33
Number of employees	[d] 10	25
Average monthly wages	9	22
Cost of materials purchased	52	29
Value of product	[e] 30	[f] 26

[a] Forty-nine establishments distributed as follows: Cavite, 14; Cebu, 5; Iloilo, 4; Rizal, 16; Zamboanga, 6; Batangas, 1; Bohol, 1; Nueva Vizcaya, 1; Sorsogon, 1.

[b] Forty-three establishments in 7 provinces.

[c] Capital, 245,952 pesos.

[d] Total number of wage earners, 841.

[e] Value, 91,284 pesos.

[f] Value, 119,470 pesos.

The various elements which make up the cost of an article of commerce are found exemplified in the simplest and clearest manner in the salt industry of the Philippines. The raw material, sea water, has no value other than that given it for the most part by unskilled labor expended in reducing it to salt and the cost of the tideland involved. In the comparative table of industries taken from the Census of the Philippine Islands, above referred to,[22] the cost of materials purchased is less than that for any other industry. The introduction of the use of reservoirs for evaporating the sea water is in the nature of a labor-saving machine, and here we have to consider the interest on the investment as part of the cost.

In the Philippines no effort is made to derive profit from the by-products. In certain localities in the United States the entire profit of the salt industry has been from by-products. In fact, in some plants the salt alone is made at a financial loss, but the bromide and calcium chloride have yielded sufficient returns to keep the furnaces active.

During the period from December 1, 1910, to May 31, 1911, more than half of the water evaporated from the ponds was returned to them by rain, so that operations on the salt farms were much interfered with and at times suspended. Out of the season

[21] Census of the Philippine Islands (1903), 4, 476–7, 486, 496, and 524.

[22] Loc. cit.

of six months it rained on thirty-two days; on eighteen of these days more water fell into the ponds than was evaporated from them. Even in the most favorable four months of this season more than one fifth of the water evaporated from the ponds was returned by rain and therefore the effective evaporation was only four fifths of the apparent. If the ponds had been covered during the whole period, four fifths as much water would have been evaporated as was evaporated in free exposure; in other words, if the ponds had been covered during the whole season, the evaporation would have been at the rate of the effective evaporation during the most favorable month, but with the proper system it would have been unnecessary to cover them except on the days when there was precipitation.

Solar salt is manufactured at Syracuse, New York, and other places by evaporating brine on so-called covers—shallow wooden vats provided with light, movable roofs arranged in such a way that they can be easily shoved over the vats when it rains. The improved process consists in the use of "aprons," or very wide, shallow troughs, in complete exposure to the sun, air, and wind, which convey the brine from the wells to the salt fields; these are 5 to 6 meters wide by 6 or 7 centimeters deep. Upon this the brine, kept at a depth of from 1 to 2 centimeters, flows slowly, depositing the gypsum and being delivered in a saturated condition to the covers. The grade is usually from 1 centimeter to 10 meters. Under the aprons are deep rooms or tanks so placed that, in case of rain, the brine on the apron can be discharged into the deep room, where it is protected from dilution, remaining there until the return of fair weather, when it is pumped back into the apron, from which all rain water has been drained. With this improvement the efficiency of a cover has been increased over 80 per cent in many instances.[23] Natural brines, which are sometimes very dilute, are often concentrated by dripping over extensive ricks composed of twigs. In the Philippines, where nipa and grass roofs are so cheap and comparatively durable, we believe a great deal might be done in the adaptation and utilization of these ideas.

The following illustration will serve to show the saving to be effected by the use of covered vats. A crystallizing pond one meter square originally costs about 1 peso; the annual upkeep is

[23] *Annual Rept. Supt. Onondaga Salt Springs, N. Y.* (1851), 27; ibid. (1869); Goessmann, C. A., Rept. on the manufacture of solar salt, Syracuse (1864); Carrignes, S. S., Statistics relating to the silica interests of Michigan, Lansing (1881), 23; Chatard, T. M., *7th Annual Rept. U. S. Geol. Surv.* (1886), 506.

about 5 centavos, and the annual yield is about 100 kilograms of salt. By the use of covers the average annual yield could be increased to 118.7 kilograms and in exceptional seasons to 153 kilograms with very little additional labor. The original cost of arranging movable roofs in such a way that they can be slid easily over the vats when it rains would not exceed 50 centavos per square meter, and the life of the roofs would be at least five years. The increased output of an average season would return 50 per cent of the additional outlay, and in exceptionally favorable seasons this would be increased three-fold. Furthermore the season could be considerably prolonged, thereby still further increasing the yield. No strong brine would ever be lost at the end of the season, as the evaporation could be finished entirely under cover, if necessary.

The fact must be recognized that the producers, in general, are not obtaining the best practical results. Many of them are unwilling to change their methods, while others cannot without previous study, for which they have neither time nor opportunity. The foundation for such a study is the collection of manufacturing statistics from the native works and their careful comparison with each other and with the best results of foreign practice. The results of our study thus far lead to the following conclusions.

CONCLUSIONS

The brine should not be transferred to the crystallizing ponds until the salt is ready to crystallize out (specific gravity, 1.205; 25°C.), for in the evaporation reservoirs large quantities of gypsum and other matter had precipitated before the salt settled out. If there is a proper balance in the plant, in at least the last two reservoirs large quantities of undesirable substances will be removed and a purer grade of salt will result.

The area occupied by the crystallizing ponds should be as small as possible to accommodate the brine concentrated in the evaporation reservoirs, for in that way as much salt is obtained with less labor. When the strength of the brine in the crystallizing ponds has attained 1.275 specific gravity (29°C.), it should be drawn off and worked over for the by-products or should be discarded. Experiments show that salt with a purity of 99.63 per cent sodium chloride may be obtained with these precautions.[24] Effort should be made to improve the quality of the output and to develop a larger industry in the Philippines.

[24] *18th Annual Rept. U. S. Geol. Surv.* (1897), 5, 1311.

ILLUSTRATIONS

PLATE VIII

FIG. 1. A view of the Filipino process, showing the loosened soil and the instruments with which the loosening is done, the canal from which the sea water is obtained, leaches in various stages of rotation, and crystallizing ponds protected from the wind.

2. A filter through which the brine is poured when it is transferred to the crystallizing vats.

PLATE IX

FIG. 1. A row of caua sheds on a dike in Binmaley, Pangasinan. In the background is an arm of the sea from which salt water is led into the depression in the foreground, where it has been evaporated and from which the impregnated earth is scraped up and leached out.

2. A crude furnace for evaporating the strong brine obtained from an improvised banca leaching vat.

3. Basket measures filled with salt for the retail trade.

PLATE X

FIG. 1. The evaporation reservoirs of a salt farm, where the salt is produced by the Chinese method.

2. The crystallizing ponds of a salt farm, where salt is produced by the Chinese method. These are built on sandy soil, and as the brine seeps through, ditches carry it to a well from which it is returned to the evaporation reservoir containing the strongest brine.

PLATE XI

FIG. 1. The salt pile and the warehouse are being built simultaneously.

2. A salt warehouse, and a day's crop from a farm, in Malabon, Rizal, where salt is produced by the Chinese method. The salt is allowed to drain in baskets for twenty-four hours before it is dumped into the warehouse.

PLATE XII

FIG. 1. The crystallizing ponds of a farm at Obando, Bulacan, using the Chinese method for making salt.

2. An apparatus used for transferring brine from evaporating reservoirs to crystallizing ponds which are on a higher level.

PLATE XIII. Salt houses at Mayinit, Bontoc.

PLATE XIV

FIG. 1. Stones incrusted with salt, Mayinit, Bontoc.

2. Washing the crust of salt from the stones, Mayinit, Bontoc.

PLATE XV

FIG. 1. Gourd used in Bontoc for storing salt meats.

2. Packages prepared for transportation. Reduction × 5.

PLATE XVI. An interior view of the salt furnace at Ahin, Ifugao subprovince, Mountain Province. The type of salt package is shown by comparison with the canteen. (Photograph taken and loaned by courtesy of Mr. H. Otley Beyer.)

PLATE XVII

FIG. 1. A near view of the Salinas salt springs, Mountain Province.
2. The lower end of the bamboo trough from the Salinas salt springs, showing the well from which the brine is carried to the evaporating pans.

TEXT FIGURES

FIG. 1. Map showing two definite types of rainfall in the Philippines.
2. Mean rainfall in the western portion of the Philippine Archipelago.
3. Mean rainfall in the eastern portion of the Philippine Archipelago.
4. Normal evaporation 1885–1907, Manila.
5. Diagram showing specific gravity of brine in the different concentration reservoirs of plants in actual operation.

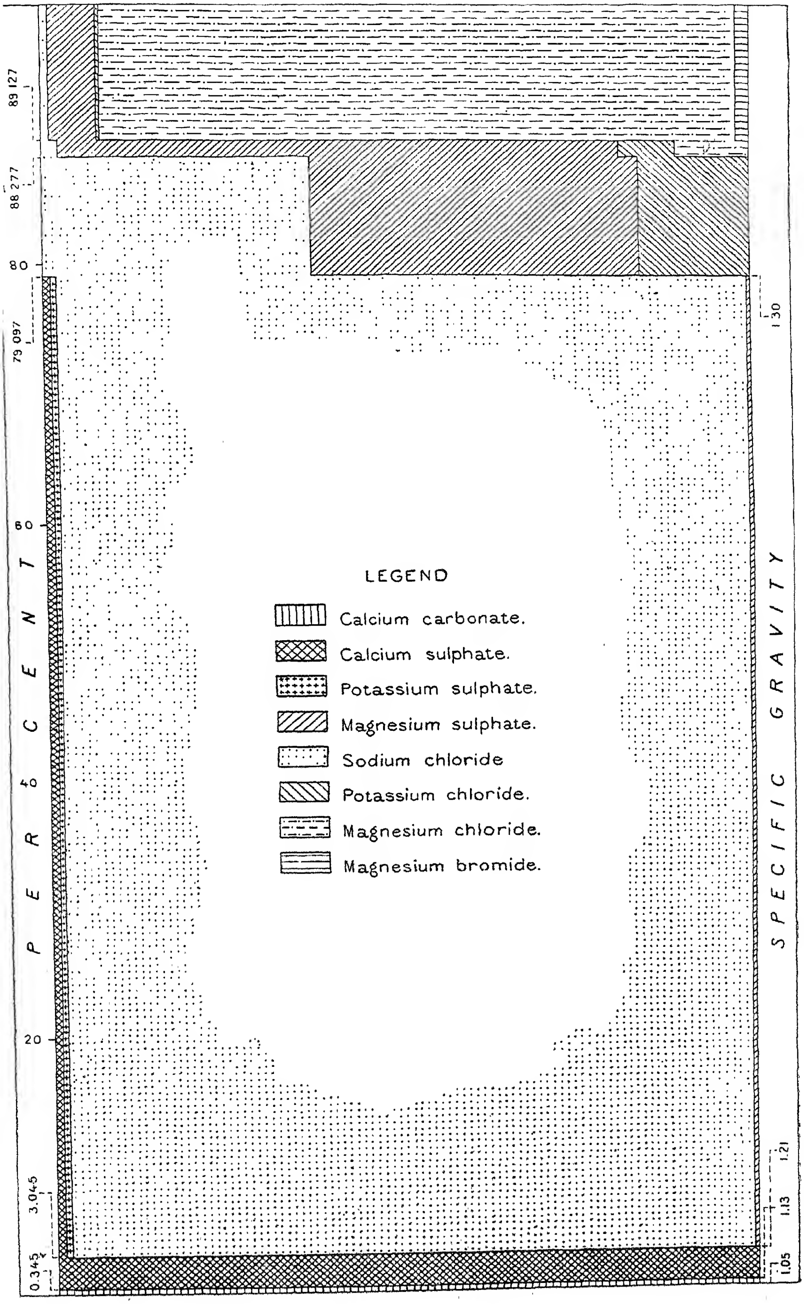

89 127
88 277
80
79 097
60
40
20
3.045
0.345
PER CENT
LEGEND
Calcium carbonate.
Calcium sulphate.
Potassium sulphate.
Magnesium sulphate.
Sodium chloride
Potassium chloride.
Magnesium chloride.
Magnesium bromide.
SPECIFIC GRAVITY
1.30
1.21
1.13
1.05

Fig. 1.

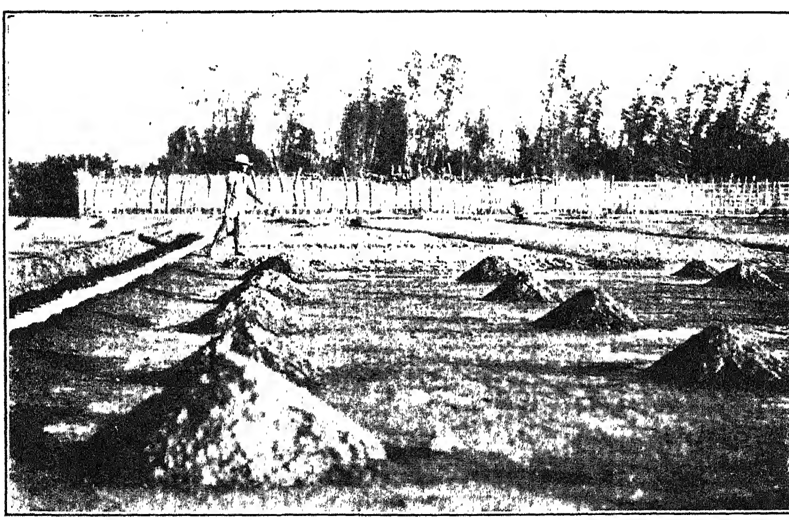


Fig. 2.

PLATE II. INSTRUMENTS USED IN SPRINKLING WATER OVER AN AREA FROM THE CANALS.

Fig. 1. Heaps of salt-impregnated earth ready for transfer to leaching vats.

Fig. 2. A leaching vat built on the ground, but high enough so that the mud may be removed by gravity after the leaching is completed.

PLATE III.

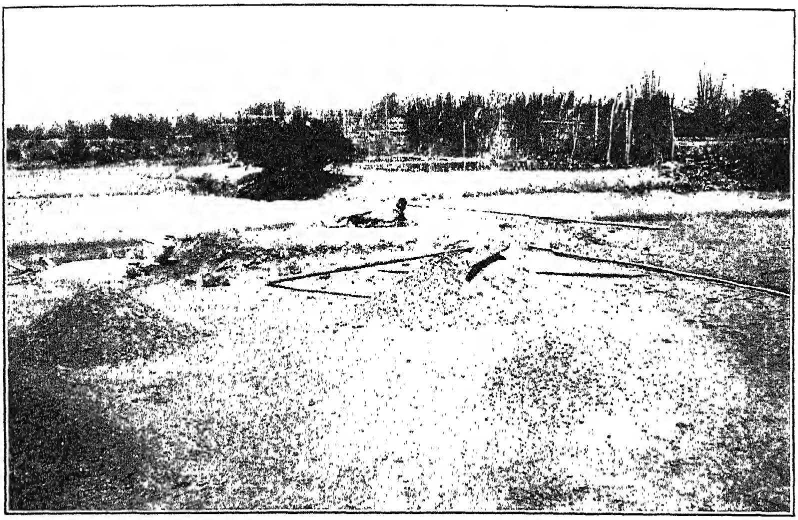


Fig. 1. Leaching vat and cement-lined receptacle into which the brine drains.

Fig. 2. Leaching vat from which leached mud has been removed.

PLATE IV.

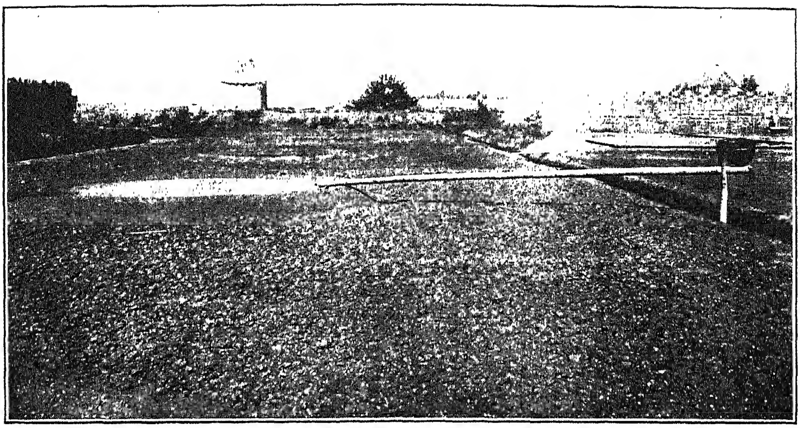


Fig. 1. Apparatus for transferring salt water from canal to leaching vat.

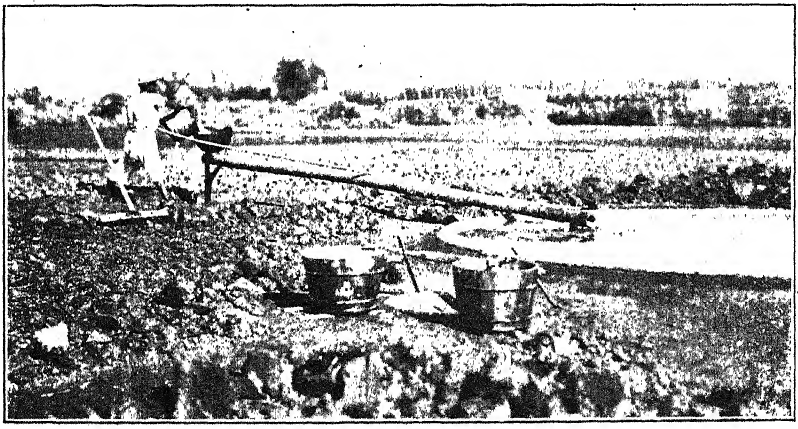


Fig. 2. The leaching process.

PLATE V.

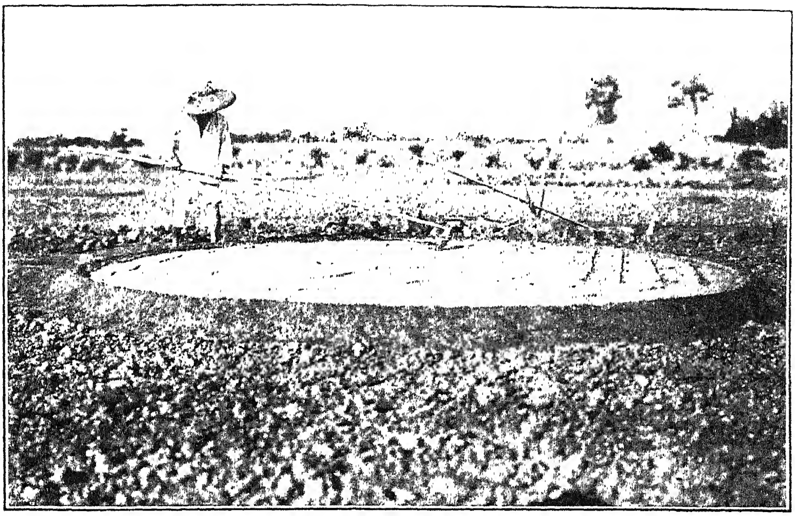


Fig. 1. Marking off the leached mud into squares.

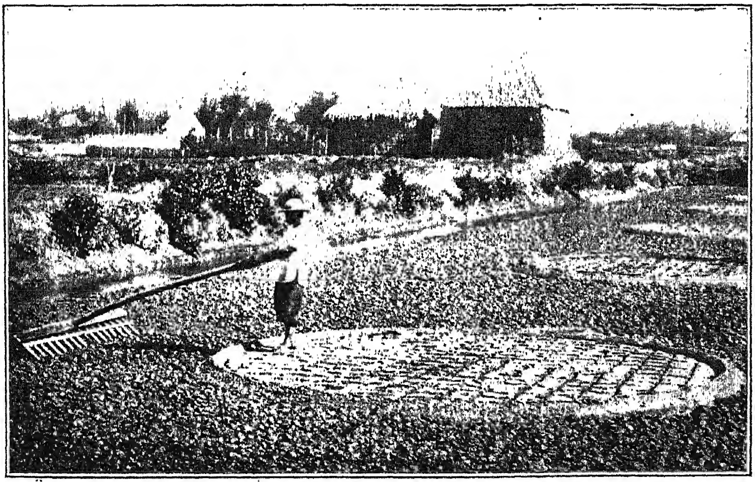


Fig. 2. A more developed and more progressive type of leach. A kind of cultivator used in loosening the soil is also shown.

PLATE VI.

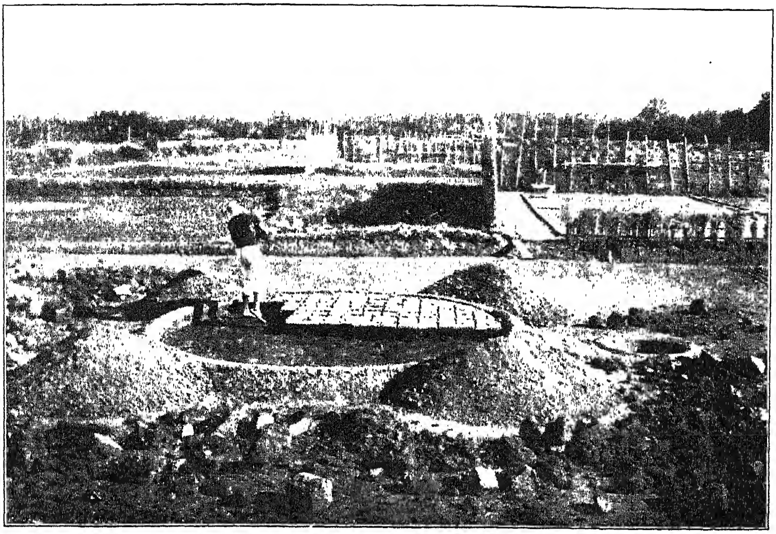


Fig. 1. Throwing the hardened blocks from the leach back on to the field.

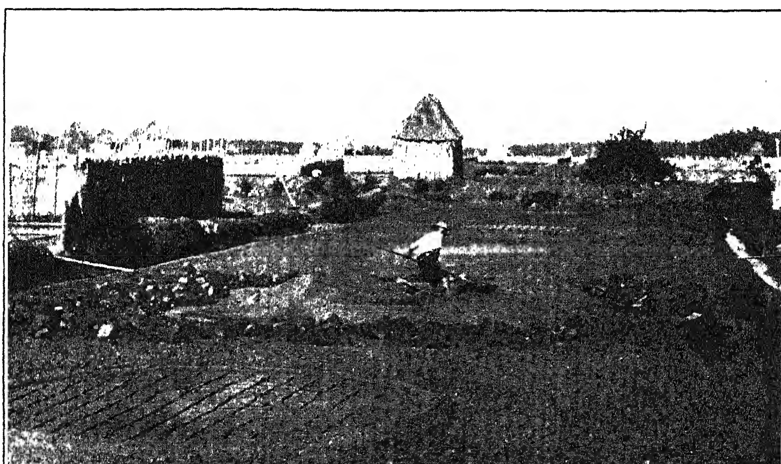


Fig. 2. Refilling a leach.

PLATE VII.

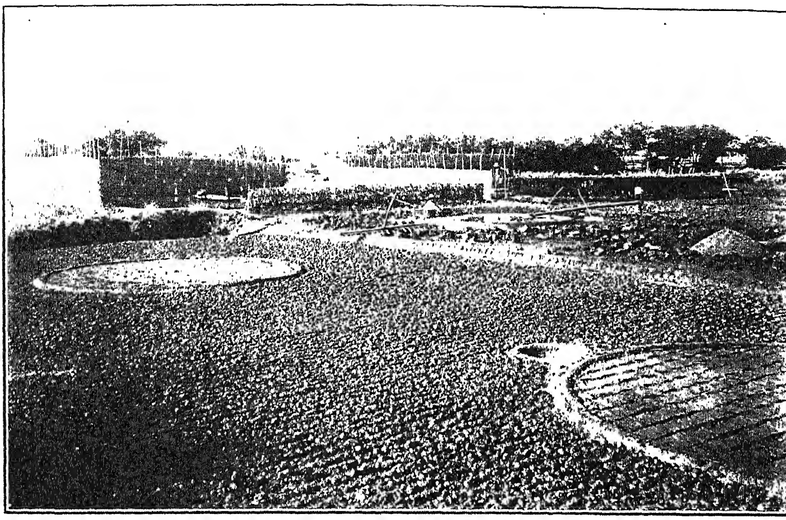


Fig. 1. Filipino process, showing instruments with which soil is loosened.

Fig. 2. Filter through which brine is poured to crystallizing ponds.

PLATE VIII.

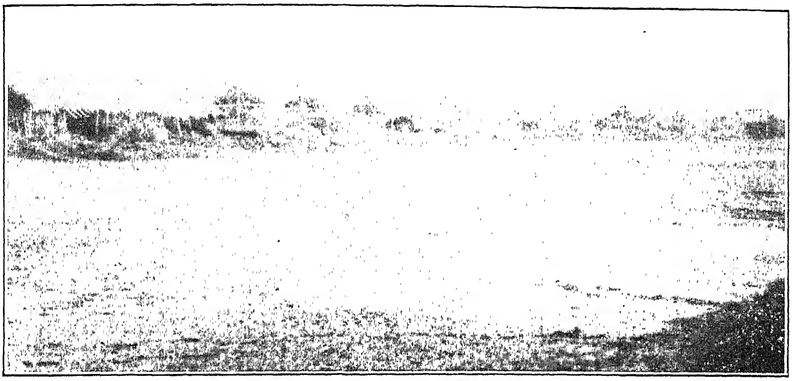


Fig. 1. A row of caua sheds on a dike.

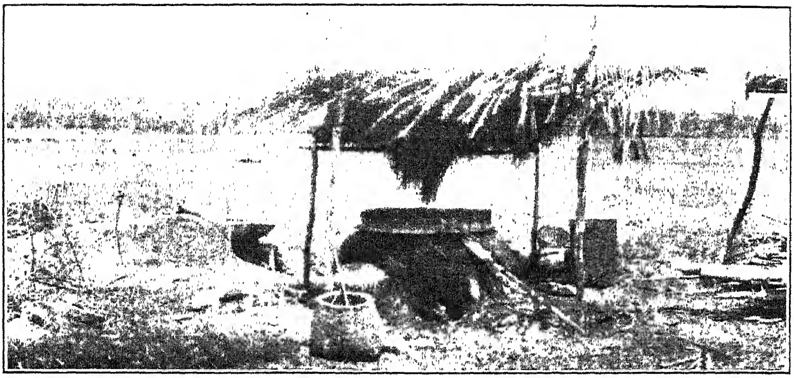


Fig. 2. Crude furnace for evaporating the strong brine.

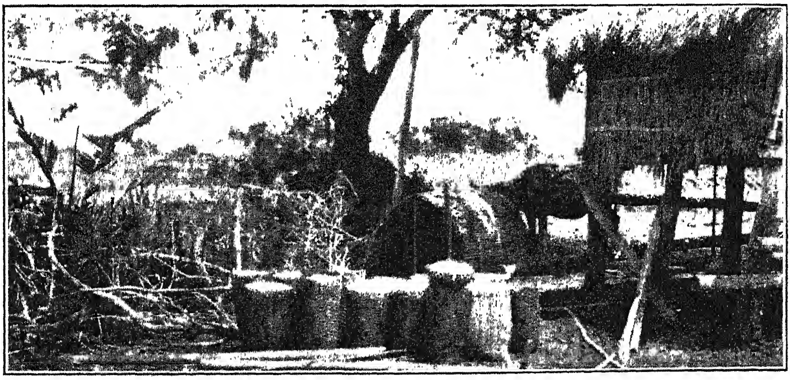


Fig. 3. Basket measures filled with salt.

PLATE IX.

Fig. 1. Evaporation reservoirs of a salt farm, where the salt is produced by the Chinese method.

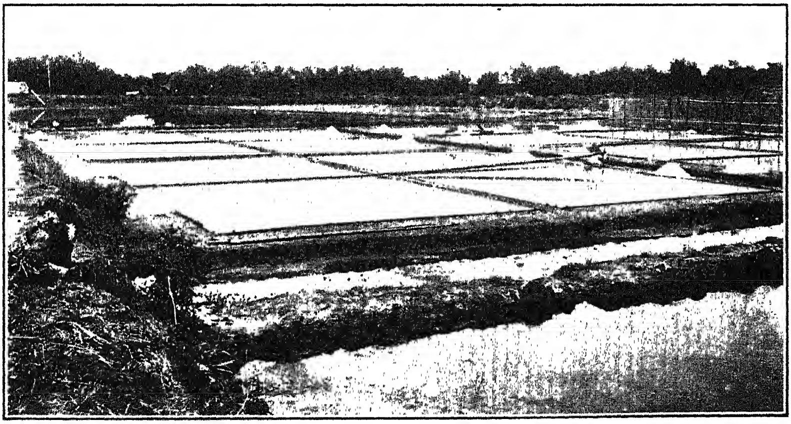


Fig. 2. Crystallizing ponds of a salt farm. Chinese method.

PLATE X.

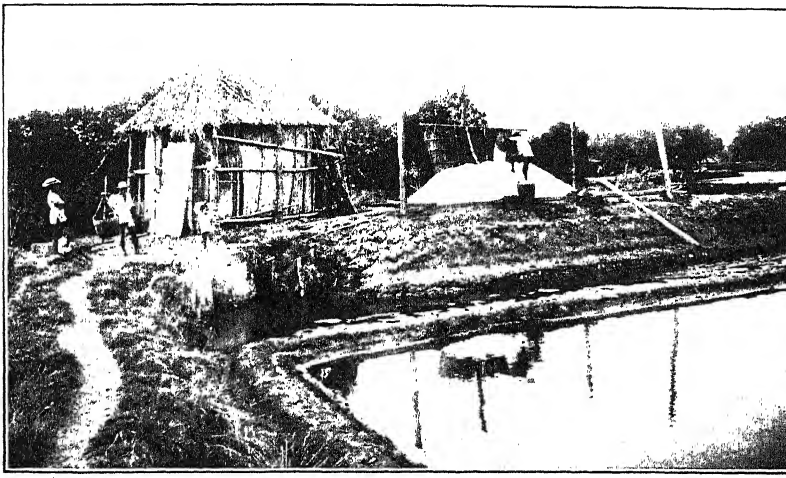


Fig. 1. Salt pile and warehouse are being built simultaneously.

Fig. 2. Salt warehouse and a day's crop.

PLATE XI.

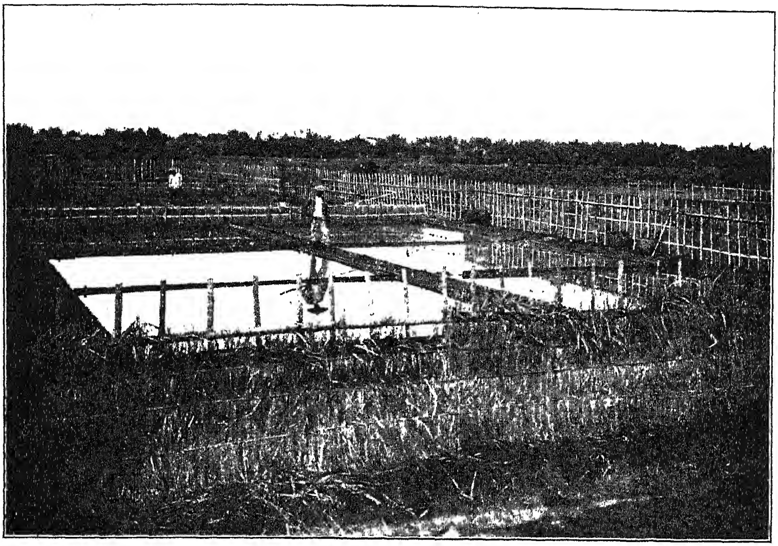


Fig. 1. The Chinese method of salt-making at Obando.

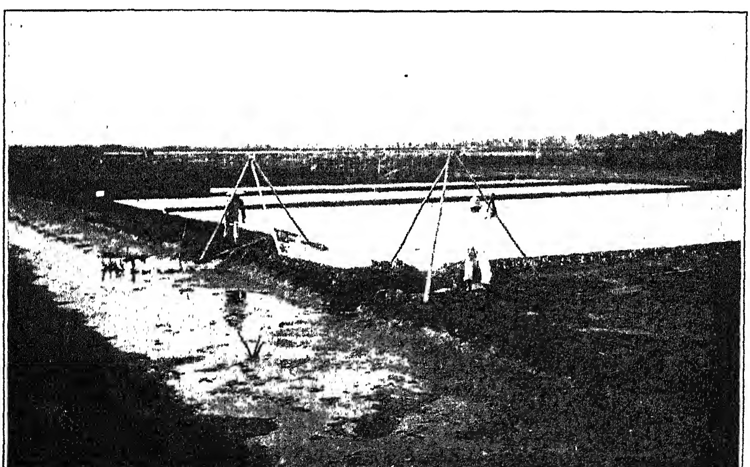


Fig. 2. Showing the apparatus for transferring brine from evaporating reservoirs to crystallizing ponds which are on a higher level.

PLATE XII.

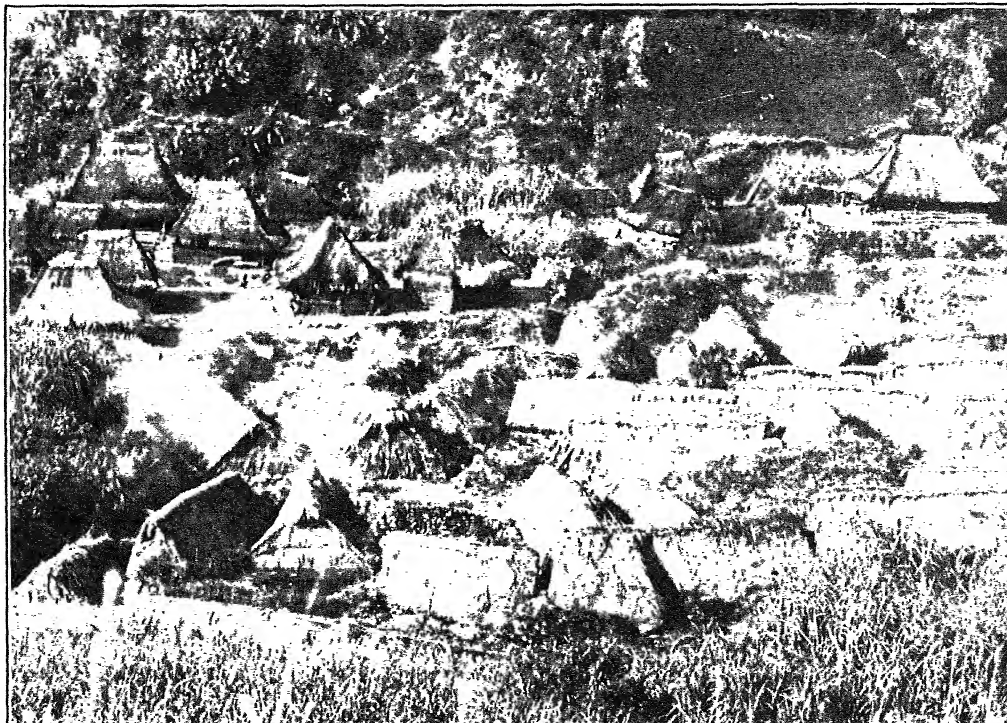


PLATE XIII. SALT HOUSES AT MAYINIT, BONTOC.

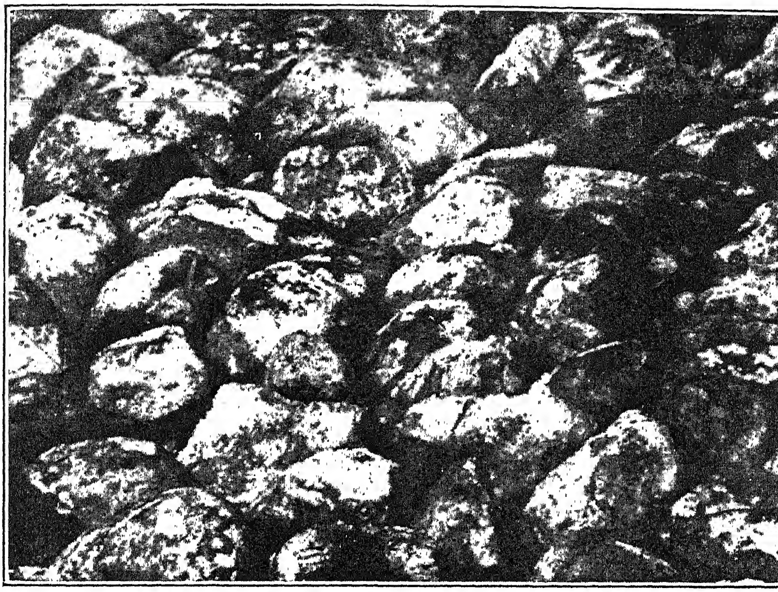


Fig. 1. Stones incrusted with salt.

Fig. 2. Washing the crust of salt from the stones.

PLATE XIV.

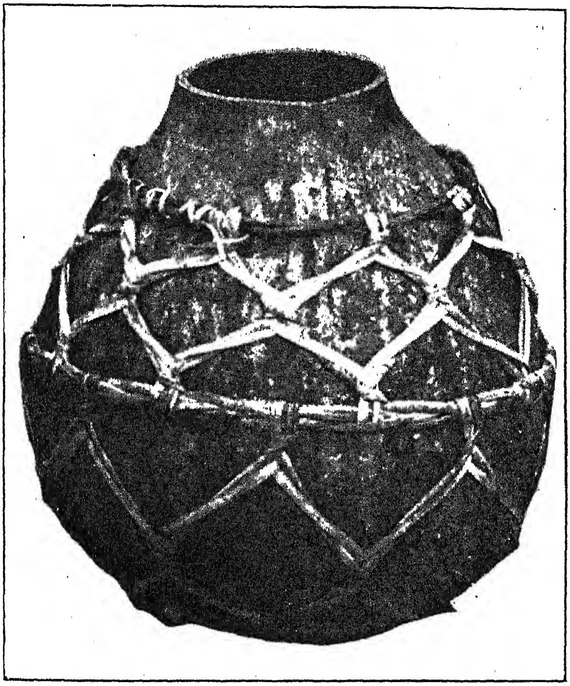


Fig. 1. Gourd for storing salt meats.

Fig. 2. Packages prepared for transportation.

PLATE XV.

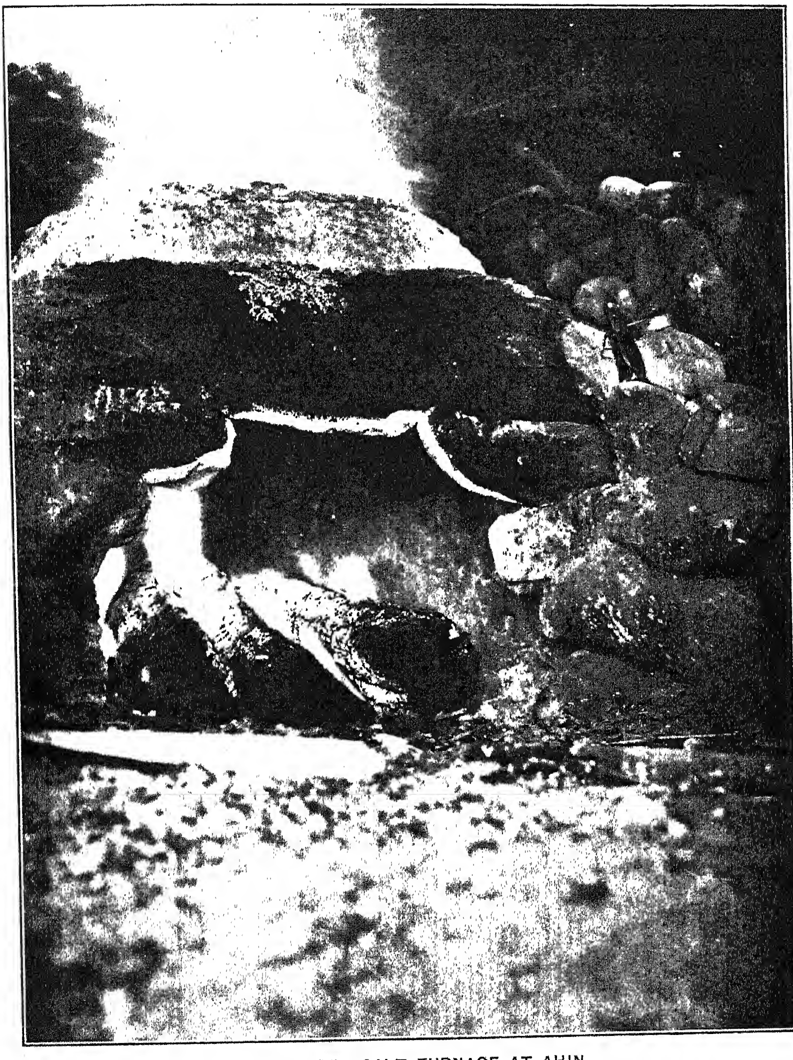


PLATE XVI. SALT FURNACE AT AHIN.

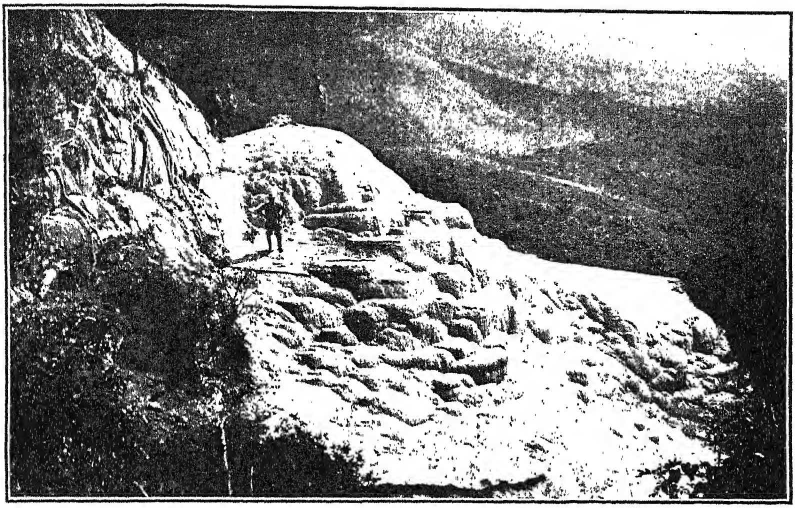


Fig. 1. Near view of the Salinas salt springs.

Fig. 2. The lower end of the bamboo trough from the Salinas salt springs, showing the well from which the brine is carried to the evaporating pans.

PLATE XVII.

INDEX

A

B

C

T

U

V

W

O